The International Center for Research on the Management of Technology

Global Benchmarking Study on the Strategic Management of Technology: The Case of Singapore

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September 1994 **WP # 114-94**

Sloan WP # 3745

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Acknowledgment

The study team would like to thank all the responding companies for their contribution to the study, the National Science and Technology Board (NSTB) of Singapore and the International Center for Research on the Management of Technology (ICRMOT) at MIT Sloan School for their sponsorship of the study, and the National University of Singapore (NUS) for partial funding of the study through a research grant. Mr. Felix Leo at the Centre for Management of Technology provided valuable assistance in data analysis, and continuing research on this project is being supported by the Centre for Management of Technology at NUS.

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1. INTRODUCTION

This report presents findings from a questionnaire survey of Singapore-based high-tech companies on their key strategic concerns and approaches towards the management of technology. The study forms part of a global study to benchmark how leading high-tech companies in the world formulate and implement technology strategies. This global study project is led by Professor Edward Roberts from the Sloan School of Management at MIT. Under Professor Roberts' direction, the project has so far covered leading high-tech firms from USA, Japan and Europe. The present study represents the first coverage of firms operating in an Asian Newly Industrialized Economy (NIE), and is conducted as a collaborative effort of MIT's International Center for Research in Management of Technology (ICRMOT), the Center for Management of Technology (CMT) at the National University of Singapore, and the National Science and Technology Board (NSTB). Besides providing a unique benchmarking of strategic management of technology of Asian NIE firms against firms from the advanced industrialized countries, the survey also serves to highlight specific management concerns that will need to be taken into account by the Singapore government in her efforts to promote technological innovation in Singapore and to leverage the strategic deployment of technology among Singapore-based companies in attaining global competitiveness.

The specific objectives of the Singapore study are:

- To identify and evaluate the technology strategies and management practices of Singapore-based high-tech firms against comparative findings for leading high-tech firms in North America, Western Europe and Japan;

- To highlight areas for improvement by Singapore-based companies in formulating and implementing effective technology strategies, in the light of the benchmarking findings.

- To highlight relevant policy implications for the Singapore government to promote Singapore as a global platform for high-tech innovation activities.

2. RESEARCH METHODOLOGY

The research project utilizes a questionnaire survey instrument that is quite similar to the one that has been used in the global study covering the most technology-intensive firms in the USA, Europe and Japan. While some new questions have been introduced to cover certain issues specific to Singapore as an Asian NIE, all aspects of strategic management of technology found to be of importance in the global study have been retained so as to maintain comparability of our study findings. The survey questionnaires were sent to a valid universe of 385 firms in Singapore which are known to have R&D activities in Singapore at the beginning of 1994. At the close of the survey at the end of May, 1994, a total of 103 valid responses were received. This represents a 27% response rate. The covered firms reported a total R&D spending of S$293 millions*, or about 51% of the estimated total R&D spending of S$578 millions by private sector firms in Singapore derived from the 1993 R&D census by NSTB.

* S$1 = US$0.68 in 1994

While the key research questions asked of the Singapore-based firms are similar to those in the MIT global study, three distinct differences need to be noted in interpreting the study findings vs. the global benchmark surveys.

Firstly, while the global study of American, Japanese and European firms in the MIT study were administered to senior technology managers in the parent headquarters, our study of high tech firms in Singapore covers both local firms headquartered in Singapore as well as the subsidiaries of foreign multinational corporations (MNCs) operating in Singapore. Given the high degree of dependence of Singapore's high tech sectors on foreign direct investment by global multinationals, restricting the study to cover only Singapore-headquartered firms would leave out a significant number of important high-tech firms which, while being subsidiaries of MNCs, typically use Singapore as a regional headquarters and often have a significant degree of autonomous power with respect to certain key strategic technology management decisions. Sixty-one out of the 103 firms that responded to the survey, or 59%, are foreign firms, versus about 54% among all firms that perform R&D in Singapore according to the R&D Census by NSTB.

Secondly, while every attempt is made to get the respondents from the MNC subsidiaries to answer the questions regarding corporate strategy as referring to the parent corporation while the business unit strategy as referring to the Singapore-based unit (or to the regional unit, if the regional headquarters is not in Singapore), it is invariably the case that the answers largely reflect the views and perspectives of the subsidiary management, which may or may not correspond to the views of the senior management at the corporate headquarters. Thus, for example, it is possible that corporate headquarters may believe that their technology strategy is communicated to and accepted by the organization as a whole, whereas managers at the regional headquarters may have a different perception. This difference in vantage point needs to be kept in mind in comparing the responses of American, European and Japanese subsidiary firms in Singapore as reported in this study versus the responses of their respective corporate headquarters as reported in the global study.

Thirdly, although some of the largest MNCs in the world are represented in our survey sample, the survey also covers quite a few smaller MNCs that are not in the league of companies in the MIT study. Coupled with the fact that most local firms are much smaller in size than the global MNCs covered by the MIT study, this means that our sample survey firms represent on the whole much smaller firms compared to those in the MIT Global Study.

3. PROFILE OF RESPONDING FIRMS

3.1 Distribution by Sector

The top five industry sectors with the most number of respondents are computer equipment and software/IT services (20.4%), chemicals/materials (18.4%), electronic components & equipment (15.5%), machinery (9.7) and telecommunications (7.8%) (see Table 3.1). Together, they account for 72% of all the respondents.

The distribution of respondent firms by industrial sectors found in our survey is broadly comparable to that for the latest R&D Census by NSTB in 1993, although the two use somewhat different classification categories. For example, the electrical/electronic sector in the NSTB R&D census accounted for 34.7% of all R&D

firms, vs. about 33% in our survey if we lump together electronic components & equipment, consumer household durables, electrical equipment and telecommunications products. Similarly, about 21% of firms covered in NSTB's R&D census were in chemicals/petrochemicals and chemicals-linked industries, vs. about 22.3% in our survey if we lump together chemicals/materials, pharmaceuticals and petroleum products. NSTB's census also recorded about 25% of R&D firms engaging in services, which are mostly IT services and software development; this is comparable to our survey's 20% for computer software/IT services plus another 3-5% from other services such as office automation, engineering services, and telecommunications services.

Table 3.1 Respondents by Industry Sector

Industry Type	Number Responded	% of Response
Computer equipment/software & IT services	21	20.4
Chemicals/materials	19	18.4
Electronic components & equipment	16	15.5
Machinery (industrial, agricultural)	10	9.7
Telecommunication products & services	8	7.8
Consumer/household durables	5	4.9
Electrical equipment	5	4.9
Food, beverages & tobacco	3	2.9
Medical equipment & supplies	3	2.9
Pharmaceuticals	3	2.9
Construction & engineering	3	2.9
Photographic & scientific equipment	2	2.9
Defense	2	2.9
Containers/packaging	1	1.0
Office products/automation	1	1.0
Petroleum	1	1.0
Number of cases	103	100

3.2 Distribution by Ownership Structure

Based on the definition of the Economic Development Board (EDB) of Singapore, about 59% of the responding firms can be classified as foreign vs. 41% local (see Table 3.2). Firms that classify themselves as multinational corporations (MNCs) make up more than 70% of the foreign firms surveyed. Among the local firms, over 40% are 100% locally-owned, with another one-quarter in the form of "government-linked companies" (GLCs), or companies which are effectively controlled by holding companies owned by the Singapore government. The high presence of such GLCs is reflective of the significant role of the Singapore government in spearheading the development of indigenous high-tech businesses.

Table 3.2 Survey Response by Type of Company

Type of Company	Number Responded	% of Response
Foreign	61	59.2
Multinational Corporation (MNC)	44	42.7
Wholly Foreign-Owned	14	13.6
Less than 30% Local-Owned	3	2.9
Local	42	40.8
More than 30% Local-Owned	13	12.6
Wholly Local Company	18	17.5
Government Linked Company (GLC)	11	10.7
Number of cases	103	100

3.3 Distribution by Location of Corporate Headquarters

All except four of the local firms have their corporate headquarters in Singapore (about 38% of all responding firms). Among the foreign firms, 38% are headquartered in the US, 34% are from Japan, 23% are European corporations, while the remaining 3 firms (5%) are headquartered in Hong Kong, Taiwan and Malaysia respectively (see Table 3.3).

Table 3.3 Respondents by Location of Corporate Headquarters

Location of Corporate Headquarters	Number Responded	% of Response
Singapore	39	37.9
USA	24	23.3
Japan	22	21.4
Europe	15	14.6
Others	3	2.9
Number of cases	103	100

Note : There is 1 local company with USA HQ, 1 local company with UK HQ, 1 local company with Japan HQ, 1 local company with Hong Kong HQ and 1 foreign company with Singapore HQ.

3.4 Distribution by Revenue Size

About one-third of the respondent companies have annual revenues of S$100 million and above, another one-third have revenues between S$20-100 mil., while the remaining one-third have revenues below S$20 mil. (see Table 3.4). As expected, foreign firms tend to have larger revenue size on average than local firms.

While the above revenue size profile seems to suggest that many R&D performing firms in Singapore are quite small in sales size, this observation needs to be made with some caution, since there is a tendency for some of the respondents to report only the sales of their own companies and omit the sales of other associate companies, also operating in Singapore, that belong to the same parent group. For

example, some firms specifically organize their R&D operations in Singapore as separate companies, completely distinct from their manufacturing and marketing operations in Singapore, perhaps out of consideration of tax-incentive qualification and administration. In particular, it is a common practice of Japanese corporations to organize their subsidiary operations in Singapore in the form of separate companies each responsible for a different strategic business unit or operational activity; consequently, the Japanese companies in our survey have rather small average sales size compared to the American and European firms (about S$114 mil. vs. about S$420 mil. for US firms and S$300 mil. for European firms). Another indication of this size anomaly of the Japanese firms in our sample is that the ratio of R&D expenditure to total sales is significantly higher for Japanese firms than for American or European firms (11% vs. 3.7% and 3.3% respectively). While it is likely that Japanese firms may indeed have higher R&D intensities than American and European firms, the magnitude of the difference suggests that the true size of the Japanese firms may have been under-reported in the survey.

Table 3.4 Respondents by Revenue Size by Local/Foreign Ownership

Revenue Size	Local %	Foreign %	Overall %
S$10 mn and less	32.5	10.9	20.0
S$10 - 20 mn	15.0	14.5	14.7
S$20 - 50 mn	15.0	16.4	15.8
S$50 - 100 mn	10.0	21.8	16.8
S$100 - 500 mn	22.5	18.2	20.0
More than S$500 mn	5.0	12.6	12.6
Total	100	100	100

3.5 Distribution by R&D Spending

Overall, only 13% of the firms reported annual R&D spending exceeding S$5 mil. The majority of the firms (50%) have R&D spending of S$1 million or less (23 foreign and 23 local firms), while another 37% have R&D spending between S$1-5 mil. (see Table 3.5).

In comparison with the R&D census by NSTB, our survey appears to be biased in favor of the larger R&D spenders. While only about 19% of all R&D firms in the census had annual R&D expenditure exceeding S$2 mil., the proportion is 27% in our survey; conversely, nearly two-thirds of R&D performers in the census had R&D spending below S$ 1 mil. annually, while the proportion is only 50% in our survey.

Table 3.5 Respondents by R&D Spending

Size of annual R&D Spending	Foreign R&D		Local R&D		Overall	
	# firms	%	# firms	%	# firms	%
S$1 mn and less	23	42.6	23	60.5	46	50.0
S$1 - 2 mn	12	22.2	9	23.7	21	22.8
S$2 - 5 mn	10	18.5	3	7.9	13	14.1
S$5 - 10 mn	5	9.3	1	2.6	6	6.5
More than S$10 mn	4	7.4	2	5.3	6	6.5
Total	54	100	38	100	92	100
Sum of R&D Spending	S$173 mn		S$84.5 mn		S$257.5 mn	
Mean R&D Spending	S$3.2 mn		S$2.2 mn		S$2.8 mn	
% R&D Spending of Overall R&D Spending	67.2		32.8		100	

In the survey, the total R&D spending reported (for the 92 firms) is S$257.5 million, of which 67.2%, or S$173 million is accounted by foreign firms. For the 11 firms that did not disclose their R&D spending in the survey, their aggregate R&D spending, according to NSTB, amount to S$35.1 million. Therefore, the total R&D spending for the firms covered in this survey (i.e. all 103 firms) is S$292.6 million, or about 51% of the estimated total R&D expenditure according to the latest R&D census by NSTB.

3.6 Distribution by Diversification of Company

About 40% of the responding companies have 1 to 2 lines of business while 36% have between 3 to 5 lines of business (see Table 3.6). As expected, compared to local firms, foreign firms on average have a higher number of lines of business.

Table 3.6 Survey Response by Diversification of Company

# Lines of Business	Local %	Foreign %	Overall %
1 - 2 lines of business	52.5	31.7	40.0
3 - 5 lines of business	37.5	35.0	36.0
6 - 10 lines of business	5.0	15.0	11.0
> 10 lines of business	5.0	18.3	13.0
Total	100	100	100

4. KEY FINDINGS

4.1 Linking Technology Strategy to Corporate and Business-Level Strategy

4.1.1 A significant proportion of companies believe they have well-communicated and accepted technology strategy

A high percentage of the responding firms indicates that their technology strategy is communicated to and well received by their organizations (see Table 4.1.1a). The proportion is similar in terms of business unit strategy and corporate technology strategy (62% vs. 60%), with foreign firms reporting slightly higher level of acceptance than local firms (see Table 4.1.1b). In terms of communication (not necessarily resulting in acceptance), however, there is no significant difference between local and foreign firms in the case of business unit strategy (74% vs. 72%). One plausible interpretation of the above is that while foreign firms generally have better articulated technology strategies than local firms, their wider geographic span vs. the local firms may make their effective communications to all parts of the organization more difficult.

Table 4.1.1a Best Description of Corporate and Business Unit Technology Strategy

Description of Technology Strategy	% of Response	
	Corporate	Business Unit
Vague or virtually non-existent	7.2	9.4
Exists and is communicated to the organization, but not well understood or accepted	22.7	17.7
Understood by organization but not generally accepted	10.3	11.5
Communicated to and accepted by the organization as a whole	59.8	61.5
Overall	100%	100%

There is a strong correlation between technology strategy development at the corporate and business unit level. Strong technology strategy development at the corporate level tends to result in strong business unit technology strategy as well. However, nearly one-third of companies that have weak corporate technology strategy still manage to have strong technology strategy development at the business unit level, indicating a certain degree of strategic initiative by business unit managers despite the lack of leadership by their corporate bosses.

Table 4.1.1b Description of Technology Strategy by Local/Foreign Ownership

Description of Technology Strategy	% of Response			
	Corporate		Business Unit	
	Local	Foreign	Local	Foreign
Vague or virtually non-existent	7.5	7.0	10.3	8.8
Exists and is communicated to the organization, but not well understood or accepted	30.0	17.5	15.4	19.3
Understood by organization but not generally accepted	12.5	8.8	17.9	7.0
Communicated to and accepted by the organization as a whole	50.0	66.7	56.4	64.9
Overall	100%	100%	100%	100%

4.1.2 External customer requirements represent the most important element of corporate technology strategy

Overall, the top three elements that respondents expect their corporate technology strategy to include are external customer requirements (68.7%), defining core technical strengths (59.8%) and competitive technology position (55.3%) (Table 4.1.2a). Differences exist between foreign and local firms, however. For local firms only, internal customer requirements and internal development vs. external access are ranked as second and third most important (after external customer requirements) (Table 4.1.2b), even though these two elements are ranked fifth and eighth respectively for foreign firms. In contrast, foreign firms place more emphasis on defining core technology strength and competitive technology position (Table 4.1.2c).

Table 4.1.2a Key Elements of Corporate Technology Strategy

Extent of Corporate Technology Strategy	% of Response			Total
	Low	Med	High	
External customer requirements	13.8	17.6	68.7	100%
Defining core technical strengths	5.9	34.3	59.8	100%
Competitive technology position	9.7	35.0	55.3	100%
Internal customer requirements	25.7	24.8	49.5	100%
Internal development vs. external access	24.0	30.0	46.0	100%
Technology mission statement	28.2	26.2	45.6	100%
Technologies competing against ours	21.6	35.3	43.1	100%
Life cycle stages of technologies	29.7	30.7	39.6	100%
Balance in portfolio of technologies	27.4	42.2	30.4	100%

Table 4.1.2b Key Elements of Corporate Technology Strategy for Local Firms

Extent of Corporate Technology Strategy	% of Response			Total
	Low	Med	High	
External customer requirements	19.0	19.0	62.0	100%
Internal customer requirements	34.2	14.6	51.2	100%
Internal development vs. external access	19.5	29.3	51.2	100%
Defining core technical strengths	7.1	42.9	50.0	100%
Competitive technology position	11.9	40.5	47.6	100%
Technologies competing against ours	19.0	40.5	40.5	100%
Technology mission statement	31.0	28.6	40.4	100%
Life cycle stages of technologies	33.3	33.3	33.3	100%
Balance in portfolio of technologies	28.6	42.8	28.6	100%

Table 4.1.2c Key Elements of Corporate Technology Strategy for Foreign Firms

Extent of Corporate Technology Strategy	% of Response			Total
	Low	Med	High	
External customer requirements	10.0	16.7	73.3	100%
Defining core technical strengths	5.0	28.3	66.7	100%
Competitive technology position	8.2	31.1	60.7	100%
Technology mission statement	26.2	24.6	49.2	100%
Internal customer requirements	20.0	31.7	48.3	100%
Technologies competing against ours	23.3	31.7	45.0	100%
Life cycle stages of technologies	27.1	28.8	44.1	100%
Internal development vs. external access	27.2	30.5	42.4	100%
Balance in portfolio of technologies	26.7	41.7	31.6	100%

4.1.3 Matching R&D to market needs is the important issue to technology management strategy

Both local and foreign companies regard matching R&D to market needs as by far the most important issue to technology management strategy (Table 4.1.3a, 4.1.3b and 4.1.3c). Interestingly, while local firms found managing R&D with constrained resources to be of second importance and total quality methods in R&D the least important (fourth), the picture is reverse in the case of foreign firms. This seems to suggest that local firms have greater difficulties in raising or justifying R&D spending than foreign firms, while the latter are more concerned with improving the quality of their R&D management.

Table 4.1.3a Important Issues to Technology Management Strategy and Processes

Rating of Following Issues	% of Response			Total
	Low	Med	High	
Matching R&D to market needs	1.9	12.6	85.4	100%
Managing R&D with constrained resources	3.9	18.4	77.7	100%
Decreasing time to market for new products	7.8	16.7	75.5	100%
Total quality methods in R&D	9.7	19.4	70.9	100%

Table 4.1.3b Important Issues to Technology Management for Local Firms

Rating of Following Issues	% of Response			Total
	Low	Med	High	
Matching R&D to market needs	2.4	7.1	90.5	100%
Managing R&D with constrained resources	4.8	7.1	88.1	100%
Decreasing time to market for new products	9.7	14.6	75.6	100%
Total quality methods in R&D	14.3	26.2	59.5	100%

Table 4.1.3c Important Issues to Technology Management for Foreign Firms

Rating of Following Issues	% of Response			Total
	Low	Med	High	
Matching R&D to market needs	1.6	16.4	82.0	100%
Total quality methods in R&D	6.6	14.7	78.7	100%
Decreasing time to market for new products	6.6	18.0	75.4	100%
Managing R&D with constrained resources	3.3	26.2	70.5	100%

4.1.4 Companies generally believe their corporate technology strategy is strongly linked to their overall corporate strategy

Overall, 62.4% of respondents consider their corporate-level technology strategies to be strongly linked to their overall corporate strategies (see Table 4.1.4). No significant difference is detected between local firms and foreign firms.

Table 4.1.4 Linkage of Corporate Technology Strategy to Overall Corporate Strategy

Strength of Linkage of Corporate Technology Strategy to Overall Corporate Strategy	% of Response
Low Medium High	9.9 27.7 62.4
Overall	100%

4.1.5 The most critical position to achieving linkage between corporate technology strategy and overall corporate strategy are CEO, followed by R&D Vice President/Director and CTO

The three key positions in achieving linkage between corporate technology strategy and overall corporate strategy are CEO, R&D Vice President/Director and CTO, with CEO being by far more important than the rest (Table 4.1.5a). For linkage between technology strategy and business-unit strategy, the three key positions are CEO, R&D VP/Director and Business Unit Mangers (Table 4.1.5b). No significant difference exists between local and foreign firms, aside from the observation that the role of CEO appears to be much stronger for local firms vs. foreign firms. The role of Finance VP/director, already small for foreign firms, is even smaller in the case of local firms, while the role of Marketing VP/Director is also lower in local firms than foreign firms. Overall, the perceived importance of the CEO, even for linkage at the business unit level, is somewhat surprising. What is even more surprising is the relatively low importance ascribed to business unit manager in linking corporate technology strategy to business unit strategy particularly for local firms. Perhaps the relatively smaller size of local firms is one explanatory factor for the greater role of CEO and, correspondingly, smaller role of business unit managers.

Table 4.1.5a Critical Positions to Achieving Linkage to Corporate Strategy

Most Critical Roles/Positions (Rank Either #1 or #2) to Achieving Linkage Between Corporate Technology Strategy and Overall Corporate Strategy	% of Response	
	Rank	
	#1	#2
Chief Executive Officer (CEO)	52.6	9.0
R&D Vice President/Director	13.8	23.0
Chief Technical Officer (CTO)	12.1	18.0
Marketing Vice President/Director	6.9	19.0
Chief Operating Officer (COO)	6.9	15.0
Business Unit Managers	5.2	10.0
Finance Vice President/Director	2.6	6.0

Note : Multiple responses allowed.

Table 4.1.5b Critical Positions to Achieving Linkage to Business-Unit Strategy

Most Critical Roles/Positions (Rank Either #1 or #2) to Achieving Linkage Between Corporate Technology Strategy and Business-Unit Strategy	% of Response	
	Rank	
	#1	#2
Chief Executive Officer (CEO)	41.1	6.5
R&D Vice President/Director	19.6	18.3
Business Unit Managers	11.6	14.0
Chief Operating Officer (COO)	8.9	11.8
Chief Technical Officer (CTO)	8.9	11.8
Marketing Vice President/Director	8.0	32.3
Finance Vice President/Director	1.8	5.4

Note : Multiple responses allowed.

Table 4.1.5c Critical Positions to Achieving Linkage by Corporate Strategy by Local/Foreign Ownership

% of Response					
Most Critical Roles/Positions	Local		Most Critical Roles/Positions	Foreign	
	#1	#2		#1	#2
CEO	58.7	14.3	CEO	48.6	5.2
R&D VP/Director	10.9	19.0	R&D VP/Director	15.7	25.9
CTO	10.9	19.0	CTO	12.8	17.2
COO	6.5	19.0	Marketing VP/Director	7.1	20.7
Marketing VP/Director	6.5	16.7	COO	7.1	12.1
Business Unit Managers	4.3	7.1	Business Unit Managers	5.7	12.1
Finance VP/Director	2.2	4.8	Finance VP/Director	2.9	6.9

Table 4.1.5d Critical Positions to Achieving Linkage by Business-Unit Strategy by Local/Foreign Ownership

% of Response					
Most Critical Roles/Positions	Local		Most Critical Roles/Positions	Foreign	
	#1	#2		#1	#2
CEO	47.6	5.4	CEO	37.1	7.1
R&D VP/Director	16.7	16.2	R&D VP/Director	21.4	19.6
COO	14.3	16.2	Business Unit Managers	14.3	12.5
CTO	9.5	8.1	Marketing VP/Director	10.0	32.1
Business Unit Manager	7.1	16.2	CTO	8.6	14.3
Marketing VP/Director	4.8	32.4	COO	5.7	8.9
Finance VP/Director	0.0	5.4	Finance VP/Director	2.9	5.4

4.2 Organizing for Technology Development and Use

4.2.1 **There is no clear trend in the extent of corporate-level control over R&D today vs. 3 years ago, although development appears to be decentralizing more than research**

Responses on the changes in the extent of corporate control of technology resources are surprisingly mixed. While 46% perceived no change compared to 3 years ago in research, nearly one-third perceived more corporate control today vs. 22% witnessing less control. The pattern for development is also mixed, although there is on the whole a greater extent of reducing corporate control compared to research (Table 4.2.1a). Interestingly, foreign firms perceived a greater degree of reducing corporate control than local firms particularly with respect to development (Table 4.2.1b). This may reflect the fact that foreign firms are on average larger than local firms, and hence felt greater pressure to decentralize control over R&D than their smaller local counterparts.

Table 4.2.1a Changes in Control of Technology Resources for R&D

Changes in Control of Technology Resources	% of Response	
	Research	Development
Less corporate-level control today	21.6	31.1
About the same corporate-level control today as 3 years ago	46.1	36.9
More corporate-level control today	32.4	32.0
Overall	100%	100%

Table 4.2.1b Changes in Control of Technology Resources by Local/Foreign Ownership

Changes in Control of Technology Resources	% of Response			
	Research		Development	
	Local	Foreign	Local	Foreign
Less corporate-level control today	19.5	23.0	16.7	41.0
About the same corporate-level control today as 3 years ago	46.3	45.9	45.2	31.1
More corporate-level control today	34.1	31.1	38.1	27.9
Overall	100%	100%	100%	100%

4.2.2 Technology resources at corporate level are organized primarily around products and markets, even for research

Technology resources controlled at the corporate level appear to be primarily organized around products and markets (Table 4.2.2a), for both local and foreign firms (Table 4.2.2b). This is true not only of development (54%), but of research as well (44%). As expected, more development work than research work is organized around business units (20% vs. 13%). What is surprising is that only 18% of research work is organized around technical disciplines. This seems to suggest that much of the research work carried out by the respondent firms are of an applied nature and oriented towards down-stream product development goals.

Table 4.2.2a Organization of Technology Resources Controlled at Corporate Level

Organization of Technology Resources	% of Response	
	Research	Development
Around products/markets	44.4	53.5
Around business units	13.1	20.2
Around projects	16.2	12.1
Around technical disciplines	18.2	8.1
Other areas	1.0	1.0
No corporate-level control	7.1	5.1
Overall	100%	100%

Table 4.2.2b Organization of Technology Resources at Corporate Level by Local/Foreign Ownership

Organization of Technology Resources at Corporate Level	% of Response			
	Research		Development	
	Local	Foreign	Local	Foreign
Around products/markets	47.5	42.4	43.9	60.3
Around business units	10.0	15.3	14.6	24.1
Around projects	12.5	18.6	19.5	6.9
Around technical disciplines	15.0	20.3	14.6	3.4
Other areas	0.0	1.7	0.0	1.7
No corporate-level control	15.0	1.7	7.3	3.4
Overall	100%	100%	100%	100%

4.2.3 Technology resources at business unit level are even more highly organized around products and markets, although project organization is also common

As expected, technology resources controlled at the business-unit level are even more highly organized around products and markets (Table 4.2.3a and Table 4.2.3b). However, around one-quarter of the R&D resources appears to be organized around projects, which may suggest that they may involve core technology developments that transcend more than one end product or market segment. Interestingly, foreign firms appear to be more product/market oriented than local firms in their R&D organization at the business unit level.

Table 4.2.3a Organization of Technology Resources Controlled at Business Unit Level

Organization of Technology Resources	% of Response	
	Research	Development
Around products/markets	53.0	60.4
Around projects	24.3	27.7
Around technical disciplines	9.0	4.0
Other areas	1.0	1.0
No corporate-level control	12.0	6.9
Overall	100%	100%

Table 4.2.3b Organization of Technology Resources at Business Unit Level by Local/Foreign Ownership

Organization of Technology Resources	% of Response			
	Research		Development	
	Local	Foreign	Local	Foreign
Around products/markets	48.8	55.9	50.0	67.8
Around projects	24.4	25.4	26.2	28.8
Around technical disciplines	7.3	10.2	7.1	1.7
Other areas	0.0	1.7	0.0	1.7
No corporate-level control	19.5	6.8	16.7	0.0
Overall	100%	100%	100%	100%

4.2.4 While R&D investment has been increasing over time, the nature of R&D work is becoming increasingly skill- or brain-intensive

While the majority of firms experienced increased R&D expenditure, R&D capital investment and R&D professional staff size from 1989 to 1993, and expect the trend to continue over the next two years, it is observed that less growth is expected in non-professional R&D staff than for professional staff (Table 4.2.4a). This seems to suggest that R&D work is becoming increasingly skill- or brain-intensive in nature. The basic pattern is the same for local and foreign firms, except that local firms expect higher growth in the future than foreign firms (Table 4.2.4b).

Table 4.2.4a Actual and Expected Changes for Some R&D Indicators

R&D Indictors	% of Response			Total
	Decrease	Same	Increase	
Actual Change 1989 - 1991				
Total R&D expenditure	5.1	28.3	66.7	100%
R&D capital investment	6.1	33.3	60.6	100%
R&D professional staff size	6.1	35.4	58.6	100%
Non-professional staff size	9.2	50.6	40.2	100%
Actual Change 1991 - 1993				
Total R&D expenditure	9.7	19.4	70.9	100%
R&D capital investment	12.6	26.2	61.2	100%
R&D professional staff size	13.7	24.5	61.8	100%
Non-professional staff size	14.4	46.7	38.9	100%
Expected Change 1993 - 1995				
Total R&D expenditure	8.7	20.4	70.9	100%
R&D capital investment	8.7	30.1	61.2	100%
R&D professional staff size	9.8	27.5	62.7	100%
Non-professional staff size	11.0	45.0	44.0	100%

Table 4.2.4b Actual and Expected Changes for Some R&D Indicators by Local/Foreign Ownership

R&D Indicators	% of Response			% of Response			Total
	Local			Foreign			
	Decr	Same	Incr	Decr	Same	Incr	
Actual Change 1989 - 1991							
Total R&D expenditure	2.6	43.6	53.8	6.7	18.3	75.0	100%
R&D capital investment	5.1	51.3	43.6	6.7	21.7	71.7	100%
R&D professional staff size	2.6	43.6	53.8	8.3	30.0	61.7	100%
Non-professional staff size	3.0	66.7	30.3	13.0	40.7	46.3	100%
Actual Change 1991 - 1993							
Total R&D expenditure	7.1	16.7	76.2	11.5	21.3	67.2	100%
R&D capital investment	7.1	28.6	64.3	16.4	24.6	59.0	100%
R&D professional staff size	7.3	17.1	75.6	18.0	29.5	52.5	100%
Non-professional staff size	8.3	47.2	44.4	18.5	46.3	35.2	100%
Expected Change 1993 - 1995							
Total R&D expenditure	2.4	19.0	78.6	13.1	21.3	65.6	100%
R&D capital investment	2.4	28.6	69.0	13.1	31.1	55.7	100%
R&D professional staff size	2.4	22.0	75.6	14.8	31.1	54.1	100%
Non-professional staff size	2.8	38.9	58.3	16.4	49.1	34.5	100%

4.2.5 There is a slight trend of increasing R&D allocation towards research and development projects of longer duration

Examination of the composition of R&D allocation by respondent firms into product/process maintenance, short-term development projects (<3 years), long-term projects (3-5 years), and research activities indicate no significant change over the period from 1991 to 1995. A slight trend of increase in longer-term projects can be discerned, for both local as well as foreign firms (Table 4.2.5).

Table 4.2.5 Mean % Breakdown of R&D Expenditure Pattern by Local/Foreign Ownership

R&D Activity	Local			Foreign			Total		
	'91	'93	'95	'91	'93	'95	'91	'92	'93
Product/process maintenance	30.5	31.5	30.4	34.1	32.5	33.5	32.5	32.0	32.2
Short term projects (< 3 yrs)	42.4	42.6	40.0	44.3	43.4	40.8	43.5	43.0	40.5
Longer term projects (> 3 yrs)	12.5	13.5	16.0	10.3	12.3	13.3	11.3	12.9	14.5
Research Activity	14.6	12.4	13.6	11.2	11.8	12.3	12.7	12.1	12.9
Total	100	100	100	100	100	100	100	100	100

4.2.6 Development commands the biggest share of funds allocated to corporate and business unit RD&E budget, followed by product technical support

On average, close to 40% of the corporate and business unit RD&E budget are allocated to development, followed by product technical support. Even for the corporate RD&E budget, research only ranks third (after product technical support), while for the typical business unit RD&E budget research ranks last, below process technical support as well (see Table 4.2.6). The pattern is surprisingly similar between local and foreign firms, despite some differences in the composition by industrial sectors.

Table 4.2.6 Mean % of Funds Allocated for Corporate vs. Business Unit RD&E Budget by Local/Foreign Ownership

R&D Activity	Local		Foreign		Total	
	Corporate	Business	Corporate	Business	Corporate	Business
Research	15.5	10.3	23.0	10.9	20.0	10.7
Development	41.6	45.5	38.9	39.0	40.0	41.6
Product technical support	25.7	25.2	20.9	32.2	22.9	29.4
Process technical support	17.2	19.0	17.2	17.9	17.1	18.3
Total	100	100	100	100	100	100

4.2.7 Corporate-level R&D function is primarily funded by corporate funds

Corporate R&D appears to be funded primarily through corporate funds, with funding by business units on a project to project basis being second in importance, followed by fixed percentage overhead tax on business unit. Funding from outside the company appears to be negligible. (see Table 4.2.7a). In contrast to local firms, foreign firms appear to rely more on taxing business unit as a fixed percentage (Table 4.2.7b).

Table 4.2.7a Funding of Corporate-Level R&D Function

Amount the Following Contributes to Corporate-Level R&D Function	% of Response (Ranking : 1 = least, 4 = most)				
	1	2	3	4	Overall
Corporate	8.3	20.8	20.8	50.0	100%
Business units as fixed %	9.4	37.5	23.4	29.7	100%
Business units on direct project by project basis	13.8	16.9	35.4	33.8	100%
Outside of the company	68.9	13.1	14.8	3.3	100%

Table 4.2.7b Funding of Corporate-Level R&D Function by Local/Foreign Ownership

Option Companies Consider as Contributing **Most** to Corporate-Level R&D Function	% of Response	
	Local	Foreign
Corporate	55.6	46.7
Business units as fixed %	14.3	37.2
Business units on direct project by project basis	36.4	32.6
Outside of the company	8.7	0.0

4.2.8 Nearly half the companies have a CTO or equivalent sitting on the Board of Directors

Nearly half of the respondents indicated that they have a CTO or equivalent who sits in the board of directors of their companies (Table 4.2.8). The proportion is surprisingly similar among local and foreign firms.

Table 4.2.8 CTOs on the Board of Directors

CTO or Equivalent Sitting on Board of Directors	% of Response
No	51.6
Yes	48.4
Overall	100

4.2.9 The role of the CTO appears to be more supportive than executive with respect to technology strategy development and implementation

The four most frequently cited roles of the CTO (or his/her equivalent) are to participate in corporate technology development, to review business unit technology strategy, to participate in business unit technology strategy development, and to review corporate technology strategy. In contrast, CTO is perceived to be less significantly involved in controlling resource allocation or in directing technology strategy development. This seems to indicate that the CTO's role is more supportive than executive with respect to technology strategy development (Table 4.2.9a). There appears to be no significant variation in the perceived roles of the CTO in local and foreign firms (Table 4.2.9b).

Table 4.2.9a Extent of the Role of the CTO

Extent of CTO's Role	% of Response			Total
	Low	Med	High	
Participates in overall corporate strategy development	20.7	9.2	70.1	100%
Directs corporate technology development	22.1	14.0	63.9	100%
Reviews corporate technology strategy	18.4	13.8	67.8	100%
Controls resource allocation between corporate and business unit R&D	29.4	25.9	44.7	100%
Controls R&D resource allocation across business units	22.9	25.3	51.8	100%
Directs business unit technology strategy development	18.2	23.9	57.9	100%
Reviews business unit technology strategy	13.5	15.7	70.8	100%
Participates in business unit technology strategy development	10.5	22.1	67.4	100%
Directs the corporate R&D organization	27.1	9.4	63.5	100%
Monitors and accesses external technology	14.9	21.8	63.2	100%
Determines company's investment in outside technologies	29.1	20.9	50.0	100%
Serves as liaison to outside organizations	22.1	26.7	51.2	100%

Table 4.2.9b Extent of Role of CTO by Local/Foreign Ownership

Extent of CTO's Role	% of Response						Total
	Local			Foreign			
	Low	Med	High	Low	Med	High	
Participates in overall corporate strategy development	13.5	10.8	75.7	26.0	8.0	66.0	100%
Directs corporate technology development	14.3	11.4	74.3	27.4	15.7	56.8	100%
Reviews corporate technology strategy	8.1	13.5	78.4	26.0	14.0	60.0	100%
Controls resource allocation between corporate and business unit R&D	22.9	22.9	54.3	34.0	28.0	42.0	100%
Controls R&D resource allocation across business units	15.1	27.3	57.6	28.0	24.0	48.0	100%
Directs business unit technology strategy development	11.1	19.4	69.4	23.1	26.9	50.0	100%
Reviews business unit technology strategy	7.9	13.1	79.0	17.6	17.6	64.7	100%
Participates in business unit technology strategy development	5.4	5.4	89.2	14.3	34.7	51.0	100%
Directs the corporate R&D organization	19.5	8.3	72.2	32.7	10.2	57.1	100%
Monitors and accesses external technology	7.9	18.4	73.7	20.4	24.5	55.1	100%
Determines company's investment in outside technologies	21.6	24.3	54.1	34.7	18.4	46.9	100%
Serves as liaison to outside organizations	10.8	24.3	64.9	30.6	28.6	40.8	100%

4.2.10 The involvement of company's CEO in technology appears to be highest in the establishment of overall R&D budget

The involvement of the CEO appears to be strongest in establishment of overall R&D budget, followed by technology strategy development, project selection/prioritization and selection of outside technology investments. Internal technology resource allocation appears to be relatively unimportant (see Table 4.2.10a). While CEOs of local firms differ somewhat from foreign firms in terms of specific ranking of importance of involvement, establishment of overall R&D budget is the top most important involvement of the CEO for both categories of firms (Table 4.2.10b).

Table 4.2.10a Involvement of CEO

Involvement of CEO	% of Response				Total
	Not involved	Reviews	Participates	Directs	
Technology strategy development	7.8	25.5	28.4	38.2	100%
Project selection/prioritization	8.8	28.4	28.4	34.3	100%
Establishment of overall R&D budget	2.9	27.5	27.5	42.2	100%
Internal technology resource allocation	10.8	32.4	41.2	15.7	100%
Selection of outside technology investments	8.8	26.5	31.4	33.3	100%

Table 4.2.10b Involvement of CEO by Local/Foreign Ownership

Involvement of CEO	% of Response Local				% of Response Foreign			
	Not involved	Reviews	Participates	Directs	Not involved	Reviews	Participates	Directs
Technology strategy development	9.8	12.2	34.1	43.9	6.6	34.4	24.6	34.4
Project selection/prioritization	0.0	19.5	34.1	46.3	14.8	34.4	24.6	26.2
Establishment of overall R&D budget	0.0	19.5	31.7	48.8	4.9	32.8	24.6	37.7
Internal technology resource allocation	4.9	24.4	48.8	22.0	14.8	37.7	36.1	11.5
Selection of outside technology investments	4.9	22.0	31.7	41.5	11.5	29.5	31.1	27.9

4.2.11 CEOs of local firms are perceived to have higher involvement in technology than CEOs of foreign firms

Local firm CEOs are perceived to have higher involvement than CEOs of foreign firms in all five dimensions of technology management (Table 4.2.10b). This may be partly due to the smaller size of local firms, which results in less delegation of authorities in general.

4.3 Relating Technology to Markets and Customers

4.3.1 Direct customer input is most extensively used at the later stages of the technology development process

The use of direct customer input is most extensive for product improvement, followed by product refinement/commercialization, and thirdly setting program objectives. Surprisingly, direct customer input was least used for obtaining innovative ideas, prototype development and concept development (see Table 4.3.1). It thus appears that customer input is being used most extensively only in the later stages of the companies' technology development process, rather than at the earlier stages where the impact may have been more significant. The pattern is broadly similar between local and foreign firms.

Table 4.3.1 Use of Direct Customer Input

Use of Direct Customer Input for Following Technology Activities	% of Response			Total
	Low	Med	High	
Product improvement	2.9	12.6	84.5	100%
Product refinement/ commercialization	6.8	20.4	72.8	100%
Setting program objectives	13.6	24.3	62.1	100%
Technology strategy development	16.5	24.3	59.2	100%
Testing	15.6	31.1	53.4	100%
Concept development	20.4	32.0	47.6	100%
Prototype development	20.4	34.0	45.6	100%
Obtaining innovative ideas	22.3	43.7	34.0	100%

4.3.2 While R&D has greater say in determining what customer inputs it needs in the case of research activities, other organizational entities have greater influence in determining customer needs in the case of development work

The R&D department is found largely to determine what customer inputs it needs in the case of research activities for 63% of the respondent firms, whereas in the case of development work, this is so for only 40% of the firms (see Table 4.3.2). Where other organizational entities have the responsibilities to determine customer needs, about one in four respondents indicate dissatisfaction with the ability of these organizational entities in obtaining and transferring information on customer needs to R&D. While not of alarming proportion, it does appear that the R&D-marketing interface is problematic in a significant number of companies (Table 4.3.2).

Table 4.3.2 Obtaining External Customer Input in Research/Development

How External Customer Input is Obtained	% of Response	
	Research	Development
R&D determines what customer inputs it needs, and obtains them	37.4	20.8
R&D identifies what customer inputs it requires, but another organizational entity obtains them	25.3	19.8
Other organizational entities have the responsibility to determine customer inputs, they obtain them and do an adequate job of transferring the information to R&D	28.3	42.6
Other organizational entities have the responsibility to determine customer inputs, but do an inadequate job in obtaining and transferring the information	9.1	16.8
Overall	100%	100%

4.4 Monitoring and Accessing Technology

4.4.1 Companies rely on internal mechanisms and customer/industry inputs rather than university to monitor technology

The most frequently used mechanism to monitor technology is internal technology steering group, followed by customer panels or input, and thirdly industry-based consortia. University and venture capital funds appear to be of low importance (see Table 4.4.1). This finding is consistent with the general observations that university-industry relations still appear to be relatively weak in most newly industrializing economies (Table 4.4.1). Interestingly, local firms rely even less on contact with university than foreign firms to monitor technology.

Table 4.4.1 Mechanisms to Monitor Technology

Mechanisms to Monitor Technology	% of Response			Total
	Low	Med	High	
Internal technology steering groups	16.7	23.5	59.8	100%
Customer panels or input	24.8	20.8	54.4	100%
Industry-based consortia	30.1	24.3	45.6	100%
Science/technology advisory boards	51.0	24.5	24.5	100%
University research consortia	55.3	23.3	21.4	100%
University liaison/affiliate programs	51.5	27.2	21.3	100%
Venture capital funds	71.5	20.6	7.8	100%

4.4.2 Companies rely more on internal R&D within divisions than central corporate research to obtain technology

As expected, internal R&D within divisions is of greater importance as a source of technology than central corporate research in the case of development work (see Table 4.4.2). In the case of research work, central corporate research is of greater importance in the case of foreign firms, but not so for local firms.

Table 4.4.2 Internal Mechanisms to Obtain Technology

Internal mechanisms to obtain technology	% of Response							
	Research Work				Development Work			
	Low	Med	High	Total	Low	Med	High	Total
Central corporate research	23.1	14.3	62.6	100%	31.9	23.4	44.7	100%
Internal R&D within divisions	18.8	25.6	55.6	100%	4.2	17.9	77.9	100%

4.4.3 Incorporation of supplier's technology and technology purchase are the most important among a wide range of external mechanisms to obtain the technology, while university technology transfer appears to be least important

While the respondent companies use a wide range of external mechanisms to obtain technology, none appears to be as important as internal R&D. For both research and development activities, the two most important external mechanisms to obtain technology are incorporation of supplier's technology and direct technology acquisition. The next three most important mechanisms are joint venture/alliance, licensing and incorporation of innovative customers' technology (see Table 4.4.3). Sponsored university research and university liaison/affiliation programs rank last in importance (13th and 14th) in the case of development work, and even in the case of research work, university ranks lowly as a source of technology. Recruitment of students from local universities similarly are of low importance as a means to obtain technology. This finding of university as a weak source of technology transfer contrasts strongly with the typical situation in most OECD countries. Another difference from an advanced industrial country like the USA is the low importance of company acquisition and equity investment in small firms as a means to obtain technology, which suggests a relative lack of innovative start-ups as a source of technology, although it may also reflect a lack of tradition of growth through acquisition.

Table 4.4.3 External Mechanisms to Obtain Technology

External mechanisms to obtain technology	% of Response									
	Research Work					Development Work				
	Low	Med	High	Total	Rank	Low	Med	High	Total	Rank
Licensing	50.5	24.2	25.3	100	4	44.4	23.2	32.4	100	4
Joint venture/alliance	52.8	20.9	26.4	100	3	45.0	21.0	34.0	100	3
Consortia	66.3	15.2	18.5	100	9	64.6	19.2	16.2	100	10
Sponsored university research	60.2	22.6	17.2	100	12	75.7	16.2	8.1	100	14
University liaison/affiliate programs	60.0	21.1	18.9	100	8	64.6	25.0	10.4	100	13
Continuing education	50.0	32.6	17.4	100	10	47.5	32.3	20.2	100	8
Recruiting students	62.0	22.8	15.2	100	13	56.6	29.3	14.1	100	11
Equity investments in small firms	81.1	7.8	11.1	100	14	74.5	14.3	11.2	100	12
Consultants/Contract R&D	52.2	28.3	19.6	100	7	50.5	27.7	21.8	100	7
Technologies acquisition	43.5	23.9	32.6	100	2	37.8	25.5	36.7	100	2
Products acquisition	47.8	31.1	21.1	100	6	42.8	27.6	29.6	100	6
Companies acquisition	64.1	18.5	17.4	100	11	63.6	19.2	17.2	100	9
Incorporation of supplier's technology	43.0	23.7	33.3	100	1	35.8	24.2	40.0	100	1
Incorporation of innovative customer's technology	48.4	28.0	23.6	100	5	39.6	28.1	32.3	100	5

4.4.4 **Local firms have greater reliance on external mechanisms to obtain technology than foreign firms, particularly licensing, incorporation of supplier's technology, and joint venture/alliance**

Overall, local firms appear to have greater reliance on external mechanisms than foreign firms (see Table 4.4.4a and 4.4.4b). The three most important mechanisms for local firms are licensing, incorporation of supplier's technology, and joint venture/alliance. In contrast, the top three mechanisms for foreign firms are technology purchase, incorporation of supplier' technology, and incorporation of innovative customer' technology. This contrasting pattern is consistent with our expectation that local firms are on the whole lagging behind the foreign firms in terms of technological level. What is surprising, however, is that local firms generally have an adverse view towards consortia (rank 14 for research work, 10 for development work), much more so than foreign firms (rank 6th and 8th respectively). This lack of a cooperative culture in R&D among local firms in Singapore contrast strongly with the situation in other East Asian countries like Taiwan and Japan.

Table 4.4.4a External Mechanisms to Obtain Technology by Research Work by Local/Foreign Ownership

External mechanisms to obtain technology	% of Response							
	Local				Foreign			
	Low	Med	High	Rank	Low	Med	High	Rank
Licensing	47.0	11.8	41.2	1	52.6	31.6	15.8	11
Joint venture/alliance	54.3	11.4	34.3	3	51.8	26.8	21.4	5
Consortia	72.2	13.9	13.9	14	62.5	16.1	21.4	6
Sponsored university research	64.9	18.9	16.2	13	57.1	25.0	17.9	8
University liaison/affiliate programs	58.8	20.6	20.6	7	60.7	21.4	17.9	9
Continuing education	55.6	19.4	25.0	5	46.4	41.1	12.5	12
Recruiting students	58.3	19.4	22.3	6	64.3	25.0	10.7	13
Equity investments in small firms	77.1	5.7	17.1	11	83.6	9.1	7.3	14
Consultants/Contract R&D	51.4	28.6	20.0	8	52.6	28.1	19.3	7
Technologies acquisition	52.8	19.4	27.8	4	37.5	26.8	35.7	1
Products acquisition	54.3	25.7	20.0	9	43.6	34.5	21.8	4
Companies acquisition	69.4	13.9	16.7	12	60.8	21.4	17.8	10
Incorporation of supplier's technology	41.7	22.2	36.1	2	43.8	24.6	31.6	2
Incorporation of innovative customer' technology	52.8	27.8	19.4	10	45.6	28.1	26.3	3

Table 4.4.4b External Mechanisms to Obtain Technology by Development Work by Local/Foreign Ownership

External mechanisms to obtain technology	% of Response							
	Local				Foreign			
	Low	Med	High	Rank	Low	Med	High	Rank
Licensing	38.5	20.5	41.0	3	48.3	25.0	26.7	6
Joint venture/alliance	41.5	17.1	41.4	2	47.5	23.7	28.8	5
Consortia	70.0	17.5	12.5	10	61.0	20.3	18.6	8
Sponsored university research	80.0	12.5	7.5	14	72.9	18.6	8.5	14
University liaison/affiliate programs	64.9	24.3	10.8	12	64.4	25.4	10.2	13
Continuing education	51.2	24.4	24.4	7	44.8	37.9	17.2	9
Recruiting students	63.4	26.8	9.8	13	51.7	31.0	17.2	10
Equity investments in small firms	73.2	14.6	12.2	11	75.4	14.0	10.6	12
Consultants/Contract R&D	53.6	22.0	24.4	8	48.3	31.7	20.0	7
Technologies acquisition	46.3	22.0	31.7	5	31.6	28.1	40.3	1
Products acquisition	52.5	20.0	27.5	6	36.2	32.8	31.0	3
Companies acquisition	65.0	17.5	17.5	9	62.7	20.3	17.0	11
Incorporation of supplier's technology	30.7	25.6	43.6	1	39.3	23.2	37.5	2
Incorporation of innovative customer' technology	40.0	25.0	35.0	4	39.2	30.4	30.4	4

4.4.5 Reliance on external sources for technology acquisition is increasing rapidly among foreign firms, but only slowly for local firms

An important contrast in technology acquisition behavior between local and foreign firms is that, while the former has much higher dependence on external sources currently and in the recent past, the degree of such external reliance is increasing very slowly, whereas in the latter case, it is expected to increase very rapidly (see Table 4.4.5). Indeed, foreign firms perceive a higher dependence on external technology three years from now than local firms, a reverse of the current and past situation. We believe that the rapid change in external technology dependence expected by foreign firms is a reflection of the significant paradigm shift among the global high-tech leaders in the world towards focusing on core competencies, strategic alliances and building external networks to better respond to global competition and rapid technological change. In contrast, local firms are more concerned at the moment with trying to catch up technologically through building up their internal technological capabilities.

Table 4.4.5 Reliance on External Sources for Technology Acquisition by Local/Foreign Ownership

Actual and Expected Reliance on External Sources for Technology Acquisition	% of Response			% of Response			Total
	Local			Foreign			
	Low	Med	High	Low	Med	High	
3 years ago	38.1	21.4	40.5	56.7	31.7	11.7	100%
Today	33.3	26.2	40.5	31.7	45.0	23.3	100%
3 years from now	21.4	35.7	42.9	18.3	30.0	51.7	100%

4.4.6 In choosing internal development vs. external technology acquisition, besides competence/ability and cost, foreign firms emphasize time/sense of urgency, while local firms are concerned with availability

In choosing between internal development and external acquisition, local firms are most concerned with own competence/ability, cost and the availability of the technology. In contrast, foreign firms place more emphasis on time and sense of urgency, followed by their own competence/ability and cost (see Table 4.4.6a & 4.4.6b).

Table 4.4.6a Choosing Between Internal and External Mechanisms for Technology Acquisition for Local Firms

Level of Importance for Following Criteria	% of Response			Total
	Low	Med	High	
Competence/ability	2.4	16.7	80.9	100%
Cost	2.4	19.0	78.6	100%
Availability	4.8	21.4	73.8	100%
Time & sense of urgency	7.2	21.4	71.4	100%
Own familiarity	16.7	28.6	54.8	100%
Intellectual property ownership	16.7	33.3	50.0	100%
Industry fit/standards	21.4	35.7	42.9	100%

Table 4.4.6b Choosing Between Internal and External Mechanisms for Technology Acquisition for Foreign Firms

Level of Importance for Following Criteria	% of Response			Total
	Low	Med	High	
Time & sense of urgency	6.6	18.0	75.4	100%
Competence/ability	1.6	24.6	73.8	100%
Cost	9.8	23.0	67.2	100%
Availability	4.9	36.1	59.0	100%
Intellectual property ownership	9.8	31.1	59.0	100%
Industry fit/standards	18.3	30.0	51.7	100%
Own familiarity	16.4	34.4	49.2	100%

4.4.7 Universities are used more for collaborative research and obtaining innovative ideas rather than to license technology

We have already pointed out earlier the low importance of universities as a source of technology to the high-tech firms covered in the survey. Such low involvement of university notwithstanding, the survey also shows that main form of interaction with the university is not to license technologies from them, but more for collaborative research and as a source of innovative ideas (see Table 4.4.7). There is also some use of universities to determine technology trends and to train company personnel, but the university as a source for modifying technology management practices remains weak (Table 4.4.7).

Table 4.4.7 Usage of University Programs for Technology Monitoring/Acquisition

Usage of University Programs for Technology Monitoring/Acquisition	% of Response			Total
	Low	Med	High	
Collaborative research efforts	48.5	29.7	21.8	100%
Obtaining innovative ideas	49.5	28.7	21.8	100%
Determining technology trends	48.5	31.7	19.8	100%
Training company personnel	54.5	26.7	18.8	100%
Modifying technology management practices	71.0	18.0	11.0	100%
Licensing product innovations	79.2	13.9	6.9	100%
Licensing process innovations	82.2	13.9	4.0	100%

4.4.8 Training of existing people is seen as most important in meeting increasing technical skill demand

Both local and foreign firms perceive significant increase in technical skills requirement in their technical staff over the last three years (see Table 4.4.8a). To respond to such increasing skills needs, training and retraining of existing people are regarded as most important, more so for foreign firms. Hiring of experienced people are next in importance, with hiring of new people directly from university the least important (see Table 4.4.8b).

Table 4.4.8a Change of Skills of Technical Staff Over Past 3 Years

Extent of Change of Skills Over Past 3 Years	% of Response
Low	8.8
Medium	40.2
High	51.0
Overall	100%

Table 4.4.8b Acquisition of New Technological Skills by Local/Foreign Ownership

Importance of Following for Acquisition of New Technological Skills	% of Response			% of Response			Total
	Local			Foreign			
	Low	Med	High	Low	Med	High	
Hire new people directly from universities	45.2	31.0	23.8	42.6	42.6	14.8	100%
Hire experienced people from competitors	45.2	21.4	33.3	47.5	24.6	27.9	100%
Train/retrain existing people	11.9	42.9	45.2	6.6	32.8	60.7	100%

4.4.9 There is an increasing stress on technical employees possessing business skills

The survey shows clearly that high-tech companies in Singapore are attaching increasing importance to their technical employees possessing business skills compared to the past (Table 4.4.9). While only 20% of the respondent firms regard this as of high importance 3 years ago, the proportion increases to 56% for today, and increases further to 82% for 3 years from now.

Table 4.4.9 Technical Employees Possessing Business Skills

Importance of Technical Employees to Possess Business Skills	% of Response			Total
	Low	Med	High	
3 years ago	47.6	32.0	20.4	100%
Today	11.7	32.0	56.3	100%
3 years from now	3.9	14.6	81.5	100%

4.5 Perceptions on R&D performance

4.5.1 Motorola, AT&T and HP are the most frequently cited R&D performance leaders in the world

A total of 121 different companies are cited by the respondent firms as among the top three R&D performers in their respective industries. In view of the high proportion of respondent firms in the electronics, information and communications technology industries, it is not surprising that the most frequently cited leading R&D performers from the survey will be statistically biased towards companies in these industries. What is interesting is that three firms stand out very clearly from the rest -- Motorola, AT&T and HP (see Table 4.5.1).

Table 4.5.1 Top R&D Companies Cited

Top R&D Companies	# Times Cited
Motorola	13
AT&T/AT&T Bell Labs	12
Hewlett Packard	12
Intel	6
Microsoft	6
IBM	5
NEC	5
Matsushita	4
Mitsubishi/Mitsubishi Electric	4
Rohm & Haas/Rohm GMBH	4
Sony	4

4.5.2 R&D is perceived to satisfy the needs of end-use customers better than that of manufacturing

Of the three "customers" of R&D -- end-use customers, corporate strategy and manufacturing -- the respondents rate their R&D performance relative to their competitors the best in the case of the end-use customers (44% think they do better than their closest competitors), and are least satisfied with respect to satisfying the needs of manufacturing (only one in four say they do better than their competitors) (see Table 4.5.2). This dissatisfaction with R&D to meet the needs of manufacturing is particularly high among local firms (only 8% think they do better than their competitors vs. 35% for foreign firms).

Table 4.5.2 Perception of R&D Performance Relative to Competitor

Perception of R&D performance relative to competitor on the following dimensions	% of Response			Total
	Worse	Same	Better	
R&D satisfies needs of end-use customers	9.8	46.1	44.1	100%
R&D satisfies needs of corporate strategy	15.8	55.4	28.7	100%
R&D satisfies needs of manufacturing	12.2	63.3	24.5	100%
Effective use of R&D resources	15.8	50.5	33.7	100%
Efficient use of R&D resources	12.0	61.0	27.0	100%
R&D's timeliness	21.6	45.4	33.0	100%
% of revenues derived from products/ processes/services not existing 5 years ago	13.9	47.5	38.6	100%
Success in reducing cost of production over past 5 years	15.0	58.0	27.0	100%
Ability to adjust to major external changes	12.9	44.6	42.6	100%

4.5.3 R&D performance is perceived to be less satisfactory in terms of production cost reduction and efficiency of use of R&D resources

Of the six criteria for evaluating R&D performance relative to their closest competitors -- R&D resource use effectiveness, R&D resource use efficiency, R&D's timeliness, % of revenue derived from products/processes/services not existing 5 years ago, success in reducing production cost, and ability to adjust to major external changes -- the respondent firms give themselves the lowest ratings in achieving production cost reduction and efficiency in R&D resource usage (see Table 4.5.2). This is true of both local and foreign firms, more so in the former case.

The lower satisfaction with production cost reduction is consistent with the earlier observation that the respondent firms' R&D performs least well in meeting the needs of manufacturing. This seems to suggest that Singapore-based high-tech firms, while being concerned with other dimensions of technological competitiveness, still perceive cost competitiveness as a major concern.

4.5.4 Majority of high-tech firms in Singapore are involved in relatively mature technologies

The majority of the high-tech firms appear to be involved in relatively mature technologies. Less than one in five of the respondent firms believe the average maturity of their technologies as being "extremely new", versus 45% as being "between new and mature" and 36% "extremely mature" (see Table 4.5.4).

Table 4.5.4 Average Maturity of Key Technologies

Average Maturity of Key Technologies	% of Response
Extremely new	19.4
Between new and mature	44.7
Extremely mature	35.9
Overall	100%

4.5.5 Local firms tend to perceive themselves more as technology followers while foreign firms perceive themselves as technology leaders

The largest proportion (40%) of the respondent firms rate their key technologies as being on par with their competitors, followed by 27% which regard themselves as technological leaders, and 33% which regard themselves as technology followers (see Table 4.5.5a). However, a strong contrast exists between local and foreign firms with respect to their evaluation of their key technologies vs. their competition. While nearly one-third of the foreign firms rate themselves as being the technological leader in their key technologies, and another 46% rate themselves as on par with their competition, the proportions are only 19% and 31% respectively in the case of local firms. Half of the local firms regard themselves as technology follower, vs. about 21% for foreign firms (see Table 4.5.5b).

Table 4.5.5a Evaluation of Company Relative to Most Serious Competitor

Evaluation of Company's Key Technologies	% of Response
Typically, we are a technology leader	27.2
We are on par with our competition	39.8
Typically, we are a fast follower	27.2
Typically, we are a later technology follower	5.8
Overall	100%

Table 4.5.5b Evaluation of Company's Key Technologies Relative to Most Serious Competitor by Local/Foreign Ownership

Evaluation of Company's Key Technologies	% of Response	
	Local	Foreign
Typically, we are a technology leader	19.0	32.8
We are on par with our competition	31.0	45.9
Typically, we are a fast follower	42.9	16.4
Typically, we are a later technology follower	7.1	4.9
Total	100%	100%

4.5.6 R&D projects have more difficulties in meeting time-to-market targets than technical specification and budgets

While 69% of the R&D projects over the past 5 years are found to have met technical specification target, the proportion of projects that met budgeted development cost is lower at 62%, and even lower (52%) with respect to meeting time-to-market target (see Table 4.5.6).

Table 4.5.6 Mean % of R&D Projects Which Met Internal Objectives by Local/Foreign Ownership

Internal Objectives	Local	Foreign	Total
Average break-even time of new products from date of first market release (#months)	16.4	16.8	16.6
% of R&D projects over past 5 years which met the time to market (%)	53.2	51.4	52.2
% of R&D projects over past 5 years which met technical specifications (%)	70.9	67.5	69.0
% of R&D projects over past 5 years which met budgeted development cost (%)	62.8	60.6	61.5

4.5.7 Foreign firms achieved greater improvement in meeting R&D project targets than local firms in recent years

On the whole, more respondent firms perceive that their ability to meet R&D project targets has improved than deteriorated over the last 3 years (Table 4.5.7). However, the trend towards improved ability is quite modest, as about 40-50% of the respondent firms perceive no change in their ability to meet R&D project targets, and sizable proportion of firms reported deterioration (19% in the case of meeting technical specification target, 25% in the case of meeting budgeted cost). Moreover, there is a larger proportion of foreign firms reporting improvement in ability to meet R&D project target than among local firms.

Table 4.5.7 Objectives Met Today vs. 3 Years Ago

Ability to Meet Internal Objectives Now Compared to 3 Years Ago	% of Response			Total
	Lower	Same	Higher	
Average break-even time of new products from date of first market release	42.0	34.1	23.9	100%
% of R&D projects which met budgeted development cost	24.7	44.7	30.6	100%
% of R&D projects which met the time to market	22.4	38.8	38.8	100%
% of R&D projects which met technical specifications	18.8	54.1	27.1	100%

4.5.8 R&D appears to receive strong support from top management

On the whole, R&D appears to receive relatively strong support from top management, as manifested by the finding that 43% of the respondent firms agree with the statement that "R&D typically gets the amount of money it requests for its budget", as well as the even higher proportion (75%) of firms that agree with the statement that "top management's attitude toward R&D is highly supportive" (see Table 4.5.8a). In line with the higher concerns about managing R&D with constrained resources among local firms as mentioned earlier, a higher proportion of local firm respondents than foreign firm respondents feel that R&D receive low top management support in their organizations (Table 4.5.8b).

Table 4.5.8a Extent of R&D Support

Extent of Support R&D Gets	% of Response			Total
	Low	Med	High	
R&D typically gets amount of money it requests for its budget	20.4	36.9	42.7	100%
Top management's attitude toward R&D is highly supportive	6.8	18.4	74.8	100%

Table 4.5.8b Extent of R&D Support by Local/Foreign Ownership

Extent of Support R&D Gets	% of Response						Total
	Local			Foreign			
	Low	Med	High	Low	Med	High	
R&D typically gets amount of money it requests for its budget	26.2	26.2	47.6	16.4	44.3	39.3	100%
Top management's attitude toward R&D is highly supportive	14.3	11.9	73.8	1.6	23.0	75.4	100%

4.5.9 There are moderate concerns with imbalance in technology portfolio in terms of not enough emphasis on longer-term, less familiar and process oriented technology development

While the majority of firms express satisfaction with the balance of their technology portfolio, there are some moderate concerns with portfolio imbalance, particularly in terms of insufficient emphasis on long and medium-to-long term projects, less familiar technologies, and technological development involving process orientation (Table 4.5.9). Local firms appear to have a slightly higher concern with portfolio imbalance than foreign firms.

Table 4.5.9 Balance of Portfolio of Technologies

Portfolio of Technologies	% of Response
Short term vs. medium term vs. long term	
Well-balanced	61.8
Not well-balanced	38.2
Not well balanced, not enough emphasis on:	
Long term	44.1
Medium to long term	20.6
Medium term	14.7
Others	14.7
Short term	2.9
Short to Medium Term	2.9
Familiar to us vs. unfamiliar to us	
Well-balanced	77.6
Not well-balanced	22.4
Not well balanced, not enough emphasis on:	
Familiarity	25.0
Unfamiliarity	50.0
Others	25.0
Product vs. process orientation	
Well-balanced	77.2
Not well-balanced	22.8
Not well balanced, not enough emphasis on:	
Product orientation	38.9
Process orientation	50.1
Others	11.1

4.6 Moving Products to Market

4.6.1 Accountability of project managers, early formation of multi-functional teams and total quality management approach are seen as most effective approaches to move products to market

Out of a list of 18 approaches to moving products to market most commonly cited in the management literatures, the three most highly rated in terms of perceived impact turn out to be accountability of assigned project managers (58% citing high impact), early formation of multi-functional team (58%) and total quality management approach (53%) (see Table 4.6.1a). Early market testing and rapid prototyping techniques also receive relatively high rating (50% and 45% respectively); indeed, the rating of these two approaches would have been higher if we have excluded responses from firms operating in certain industries where they tend to be less applicable.

There is not much significant variations between foreign and local firms in terms of the most important approaches that they employ in moving products to market (see Table 4.6.1b). Four of the top five most important approaches for local firms are also in the top five for foreign firms; the latter ranks simultaneous engineering product development process slightly higher than rapid prototyping techniques, the reverse of the case for local firms. Foreign firms also tend to rate Flexible Manufacturing Systems,

Quality Function Deployment techniques and Computer-aided Manufacturing somewhat more highly than local firms (see Table 4.6.1c).

Table 4.6.1a Approaches Used in Moving Products to Market

Impact of Approach Used	% of Response			Total
	Lower	Same	Higher	
Accountability of assigned project managers	22.3	19.4	58.3	100%
Early formation of multi-functional teams	24.3	17.5	58.2	100%
Total Quality Management approach	28.2	18.4	53.4	100%
Early market testing	32.0	18.4	49.5	100%
Rapid prototyping techniques	32.0	23.3	44.7	100%
Simultaneous engineering product development process	39.8	16.5	43.7	100%
Flexible manufacturing systems	42.8	15.5	41.7	100%
Senior management sponsors	41.8	18.4	39.8	100%
Computer-aided design/engineering	43.7	19.4	36.9	100%
Formal product champions	46.6	19.4	34.0	100%
Permanent project management function	48.6	18.4	33.0	100%
Reduction in number of parts	53.9	14.7	31.4	100%
Quality Functional Deployment techniques	51.4	17.5	31.1	100%
Early freezing of design specifications	57.3	20.4	22.3	100%
Computer-aided manufacturing	63.1	14.6	22.3	100%
"Stage-Gate" product development process	54.4	24.3	21.3	100%
More use of outside vendors	51.0	29.4	19.6	100%
Special-designated idea generators	56.3	24.3	19.4	100%

Table 4.6.1b Approaches Used in Moving Products to Market by Local Firms

Impact of Approach Used	% of Response			Total
	Lower	Same	Higher	
Early formation of multi-functional teams	33.3	11.9	54.8	100%
Accountability of assigned project managers	33.3	14.3	52.4	100%
Early market testing	28.6	21.4	50.0	100%
Rapid prototyping techniques	35.7	14.3	50.0	100%
Total Quality Management approach	33.3	21.4	45.2	100%
Senior management sponsors	52.3	4.8	42.9	100%
Simultaneous engineering product development process	42.8	16.7	40.5	100%
Computer-aided design/engineering	40.5	21.4	38.1	100%
Flexible manufacturing systems	45.2	16.7	38.1	100%
Reduction in number of parts	53.6	9.8	36.6	100%
Formal product champions	47.6	16.7	35.7	100%
Permanent project management function	52.3	14.3	33.4	100%
Early freezing of design specifications	52.3	16.7	31.0	100%
More use of outside vendors	46.4	26.8	26.8	100%
Specially-designated idea generators	50.0	26.2	23.8	100%
Quality Functional Deployment techniques	57.2	19.0	23.8	100%
"Stage-Gate" product development process	59.5	23.8	16.7	100%
Computer-aided manufacturing	69.1	21.4	9.5	100%

Table 4.6.1c Approaches Used in Moving Products to Market by Foreign Firms

Impact of Approach Used	% of Response			Total
	Lower	Same	Higher	
Accountability of assigned project managers	14.7	23.0	62.3	100%
Early formation of multi-functional teams	18.1	21.3	60.6	100%
Total Quality Management approach	24.6	16.4	59.0	100%
Early market testing	34.4	16.4	49.2	100%
Simultaneous engineering product development process	37.7	16.4	45.9	100%
Flexible manufacturing systems	41.0	14.7	44.3	100%
Rapid prototyping techniques	29.5	29.5	41.0	100%
Senior management sponsors	34.4	27.9	37.7	100%
Computer-aided design/engineering	45.9	18.0	36.1	100%
Quality Functional Deployment techniques	47.5	16.4	36.1	100%
Formal product champions	45.9	21.3	32.8	100%
Permanent project management function	45.9	21.3	32.8	100%
Computer-aided manufacturing	59.0	9.8	31.1	100%
Reduction in number of parts	54.1	18.0	27.9	100%
"Stage-Gate" product development process	50.8	24.6	24.6	100%
Early freezing of design specifications	60.6	23.0	16.4	100%
Specially-designated idea generators	60.6	23.0	16.4	100%
More use of outside vendors	54.1	31.1	14.8	100%

4.6.2 There is greater variance in performance with respect to meeting product commercialization target date than process implementation target date

On the whole, the respondent firms appear to experience greater variance in meeting product commercialization target date than for meeting target date for process implementation; while a slightly greater proportion of firms tend to be rather successful in meeting product commercialization target date than process implementation target date, there is also a greater proportion of firms that report being rather unsuccessful for product commercialization vs. process implementation (see Table 4.6.2).

Table 4.6.2 Meeting of Target Date

Extent of Meeting Target Date	% of Response			Total
	Low	Med	High	
Product commercialization	27.0	34.0	39.0	100%
Process implementation	18.0	47.0	35.0	100%

4.7 Responding to Global Technological Issues

4.7.1 Local firms have significantly lower level of non-domestic technology-related activity

Local firms have a significantly lower level of technology-based activities outside of their domestic base (see Table 4.7.1a) as compared to the foreign firms. In particular, while 39% of foreign firms perceive significant involvement in R&D in non-domestic countries, the proportion is only 17% for local firms. More foreign firms than local firms (27% vs. 22%) perceive significant involvement in joint technology development with companies from other countries. Only in the area of technology acquisition and licensing of technology from companies in other countries do local firms perceive similar level of involvement as foreign firms (Table 4.7.1b).

Table 4.7.1a Level of Non-Domestic Activity by Local Firms

Level of Non-Domestic Activity	% of Response			Total
	Low	Med	High	
Joint technology development with companies from other countries	56.5	21.7	21.7	100%
License of technology from other countries	65.2	13.0	21.7	100%
Acquisition of technology through acquisition of non-domestic companies or products	72.7	9.1	18.2	100%
Own labs in non-domestic countries	73.9	8.7	17.4	100%

Table 4.7.1b Level of Non-Domestic Activity by Foreign Firms

Level of Non-Domestic Activity	% of Response			Total
	Low	Med	High	
Own labs in non-domestic countries	31.9	29.5	38.6	100%
Joint technology development with companies from other countries	46.6	26.7	26.7	100%
Acquisition of technology through acquisition of non-domestic companies or products	53.3	26.7	20.0	100%
License of technology from other countries	57.8	24.4	17.8	100%

4.7.2 Although local firms tend to focus their more direct involvement in technological development activities in the Asia-Pacific region, they acquire and license technologies more from North America and Western Europe

As is to be expected, local firms tend to be much more geographically focused with respect to their direct involvement in technological activities when compared to the foreign firms which are much more globalized (see Table 4.7.2a and 4.7.2b). In particular, the biggest proportion of local firms (50%) that have their own R&D labs outside Singapore have these labs located within the Asia-Pacific region; similarly,

40% of their joint technology development activities with companies in other countries are carried out within the Asia-Pacific region. In contrast, where acquisition of technologies from other countries is concerned, North America and Western Europe dominate over Asia Pacific (50% and 25% respectively vs. 17% for Asia-Pacific); similar domination by North America and Western Europe is observed in the case of technology licensing (47% and 33% vs. 20% in Asia-Pacific) (Table 4.7.2a). For foreign firms, all four types of non-domestic technology activities are geographically more broadly spread across the three regions of North America, Western Europe and Asia-Pacific, including some involvement in Latin America and Eastern Europe (Table 4.7.2b).

Table 4.7.2a Location where Technology Activities are Carried Out by Local Firms

Location of Technology Activities	% of Response
Home base region	
Asia Pacific	96.0
Western Europe	4.0
North America	0.0
License of technology from other countries	
North America	46.7
Western Europe	33.3
Asia Pacific	20.0
Latin America	0.0
Eastern Europe	0.0
Joint technology development with other countries' companies	
Asia Pacific	40.0
North America	33.3
Western Europe	20.0
Eastern Europe	6.7
Latin America	0.0
Acquisition of technology through acquisition of non-domestic companies or products	50.0
North America	25.0
Western Europe	16.7
Asia Pacific	8.3
Eastern Europe	0.0
Latin America	
Own labs in non-domestic countries	
Asia Pacific	50.0
North America	33.3
Western Europe	16.7
Eastern Europe	0.0
Latin America	0.0

Table 4.7.2b Location where Technology Activities are Carried Out by Foreign Firms

Location of Technology Activities	% of Response
Home base region	
Asia Pacific	43.5
North America	39.1
Western Europe	17.4
License of technology from other countries	
North America	31.6
Asia Pacific	31.6
Western Europe	29.8
Latin America	5.3
Eastern Europe	1.7
Joint technology development with other countries' companies	
Asia Pacific	37.0
North America	29.6
Western Europe	29.6
Latin America	1.9
Eastern Europe	1.9
Acquisition of technology through acquisition of non-domestic companies or products	39.1
North America	30.4
Western Europe	21.7
Asia Pacific	4.4
Latin America	4.4
Eastern Europe	
Own labs in non-domestic countries	
Asia Pacific	38.8
Western Europe	29.8
North America	22.4
Latin America	6.0
Eastern Europe	3.0

4.7.3 Both local and foreign firms are rapidly internationalizing their R&D activities

Both local and foreign firms experienced an increase in non-domestic R&D activities over the last 3 years, and they expect the trend to accelerate over the next 3 years (Table 4.7.3). While foreign firms have nearly twice the level of R&D internationalization of local firms currently, the trend of increase in R&D internationalization appears to be stronger among local firms (expected increase from 15% 3 years ago to 24% 3 years from now, vs. 25% to 36% for foreign firms).

Table 4.7.3 Mean % of Company's Non-Domestic R&D Activity by Local/Foreign Ownership

% of Company's Non-Domestic R&D Activity	Local	Foreign	Total
3 years ago	14.8	25.1	21.6
Today	16.6	30.1	25.6
3 years from now	24.3	36.1	32.2

4.7.4 Non-domestic R&D activities tend to be different from those performed in domestic R&D facilities

Geographic specialization of R&D activities is clearly evident from the survey. Overall, in less than 30% of the respondent firms are non-domestic R&D activities performing similar activities as domestic R&D. Over 37% of the respondent firms characterize their overseas R&D as focusing on a particular phase of the R&D process, while another 34% believe their overseas R&D represent worldwide "centers of excellence" for a particular technology or discipline (see Table 4.7.4a). This pattern of geographic specialization is stronger among foreign firms than among local firms (Table 4.7.4b and Table 4.7.4c).

Table 4.7.4a Function of Company's Non-Domestic R&D Facilities

Function of Non-Domestic R&D Facilities	% of Response
Focus on a particular phase of the R&D process	37.1
Represent worldwide "centers of excellence" for a particular technology, discipline	33.9
Perform the same activities as domestic R&D facilities	29.0
Overall	100%

Table 4.7.4b Function of Company's Non-Domestic R&D Facilities by Local Firms

Function of Non-Domestic R&D Facilities	% of Response
Perform the same activities as domestic R&D facilities	37.5
Represent worldwide "centers of excellence" for a particular technology, discipline	31.3
Focus on a particular phase of the R&D process	31.3
Overall	100%

Table 4.7.4c Function of Company's Non-Domestic R&D Facilities by Foreign Firms

Function of Non-Domestic R&D Facilities	% or Response
Focus on a particular phase of the R&D process	39.1
Represent worldwide "centers of excellence" for a particular technology, discipline	34.8
Perform the same activities as domestic R&D facilities	26.1
Overall	100%

4.7.5 Non-domestic R&D activities are moderately independent from corporate control

The non-domestic R&D activities of the respondent firms appear to be moderately independent of corporate control, more so in terms of how such activities are carried out than what R&D can be carried out (Table 4.7.5). The pattern appears to be similar between local and foreign firms.

Table 4.7.5 Independence of Non-Domestic R&D Activities from Corporate Control

Extent of Independence of Non-Domestic R&D Activities from Corporate Control	% of Response			Total
	Low	Med	High	
In terms of what they do	28.6	30.1	41.3	100%
In terms of how they do it	17.5	25.4	57.1	100%

4.7.6 Technology transfer from originating country to other locations is mostly done through training in the recipient countries, documentation and relocation of internal technical experts to the recipient countries

The three most commonly used approaches to transfer technology from originating country to other location are training programs in the recipient countries, documentation transfer, and relocation of internal technical experts to the recipient countries (see Table 4.7.6). This is true for both local and foreign firms.

Table 4.7.6 Technology Transfer Approaches

Common Approach to Technology Transfer	# Times Cited
Training programs in the recipient countries	46
Documentation	43
Relocation of internal technical experts to recipient countries	40
Conferences	18
Planning sessions	14
Reports	13

4.7.7 Local firms are less engaged in monitoring technology developments in other countries than foreign firms, and rely on less sophisticated methods

Local firms are less extensively involved in monitoring technology development in other countries than foreign firms, and emphasize the use of less direct methods than foreign firms. For foreign firms, the most direct but relatively costly methods of monitoring through own company staff liaison in other countries and having own R&D labs in other countries are used most extensively, followed by reliance on external newsletters and reports (see Table 4.7.7b). For local firms, external newsletters and reports, which provide intelligence that are non-exclusive and generally less recent, is by far the most extensively used source. This is followed by own company staff liaison in other countries, and thirdly through participation in international consortia (Table 4.7.7a). There is some limited use of consultants from other countries by both local and foreign firms, but local firms hardly tap foreign universities' resources, whether through liaison/affiliate programs or sponsored research.

Table 4.7.7a Monitoring Technology Developments by Local Firms

Extent of Usage of Following to Monitor Technology Developments in Other Countries	% of Response			Total
	Low	Med	High	
Newsletters, reports	9.5	28.6	61.9	100%
Company's staff liaison in other countries	50.0	20.0	30.0	100%
Participation in international consortia	60.0	25.0	15.0	100%
Own labs in other countries	80.0	5.0	15.0	100%
Consultants from other countries	57.2	33.3	9.5	100%
Affiliate programs at foreign universities	89.5	5.3	5.3	100%
Formal technical panels of outsiders	70.0	25.0	5.0	100%
Sponsored research at foreign universities	89.5	10.5	0.0	100%

Table 4.7.7b Monitoring Technology Developments by Foreign Firms

Extent of Usage of Following to Monitor Technology Developments in Other Countries	% of Response			Total
	Low	Med	High	
Company's staff liaison in other countries	28.2	23.9	47.9	100%
Own labs in other countries	36.2	19.1	44.7	100%
Newsletters, reports	23.0	35.4	41.6	100%
Participation in international consortia	41.3	32.6	26.1	100%
Consultants from other countries	55.3	29.8	14.9	100%
Sponsored research at foreign universities	67.4	21.7	10.9	100%
Formal technical panels of outsiders	65.2	26.1	8.7	100%
Liaison/affiliate programs at foreign universities	73.9	23.9	2.2	100%

4.7.8 The non-domestic R&D of foreign firms are more centered on accessing technologies, whereas local firms are more concerned with adapting products in other countries

Local firms also differ somewhat from foreign firms in the criteria they use for investing in non-domestic R&D activities. While foreign firms on the whole emphasize most the benefit of taking advantage of technology developed by foreign organizations and of keeping abreast of foreign technologies, local firms are most concerned with adapting products to local requirements and regulations, with taking advantage of technology developed by foreign organizations only of second importance (4.7.8a and 4.7.8b).

Table 4.7.8a Criteria for Deciding Usage of Non-Domestic R&D by Foreign Firms

Significance of Criteria Used in Deciding to Utilize Some Form of Non-Domestic R&D	% of Response			Total
	Low	Med	High	
To take advantage of technology developed by foreign organizations	10.0	20.0	70.0	100%
To keep abreast of foreign technologies	25.0	15.0	60.0	100%
To adapt products to local requirements, regulations etc.	30.0	30.0	40.0	100%
To support local manufacturing capability	47.4	15.8	36.8	100%

Table 4.7.8b Criteria for Deciding Usage of Non-Domestic R&D by Local Firms

Significance of Criteria Used in Deciding to Utilize Some Form of Non-Domestic R&D	% of Response			Total
	Low	Med	High	
To adapt products to local requirements, regulations etc.	12.8	29.8	57.4	100%
To take advantage of technology developed by foreign organizations	22.9	37.5	39.6	100%
To support local manufacturing capability	34.0	27.7	38.3	100%
To keep abreast of foreign technologies	33.4	37.5	29.1	100%

4.8 Establishing the R&D Function in Singapore

4.8.1 Both local and foreign firms establish R&D in Singapore primarily for competitive reasons, and only secondarily because of what Singapore has to offer

Last but not least, local firms' criteria for establishing R&D in Singapore differ from those of foreign firms in certain respects, but also share some common ones. Basically, both local and foreign firms are driven to have R&D in Singapore primarily due to competitive reasons (global in the case of local firms, regional in the case of foreign firms), and only secondarily because of what Singapore has to offer in terms of government incentives, infrastructure support, and local R&D resources.

For foreign firms, the two most significant reasons for establishing their R&D in Singapore are to develop/adapt products to local or regional markets, and to be close to lead users/customers. Both these criteria are primarily driven by end-user markets in the region. The third most important reason is to enhance local manufacturing capabilities, which is driven by prior manufacturing investment decision. The desire to establish a "center of excellence" in the Asia-Pacific region, which is also driven by regional consideration, are ranked fourth, ahead of the desire to take advantage of infrastructure support and government incentives in R&D. Tapping of local R&D manpower and taking advantage of technological capabilities of local organizations are ranked the least important (Table 4.8.1). Overall, the picture is one of foreign firms primarily driven to have R&D in this region to compete better in the regional market, and only secondarily choose Singapore because of what she has to offer.

In the case of local firms, as Singapore is their home-base, the primary reasons why they establish R&D in Singapore are also their primary reasons for having any R&D at all. Two key reasons stand out: to keep up with technological changes in the market, and to develop innovative products for the global market. The first reason reflects the fact that Singaporean firms are still largely technology followers needing to respond quickly to technological innovations initiated by others, while the second reason reflects their desire to become product innovators themselves. That this global market oriented product innovation drive is ranked ahead of the objective to develop/adapt products to local and regional markets partly reflects the fact that the

mix of industries that the respondent firms are in is dominated by global competition (particularly electronics and information technology), but also suggests a healthy global mindset on the part of local firms. This is consistent with the fourth rank reason of using R&D in Singapore to support their internationalization drive. The need to support own manufacturing/processing capabilities is ranked fifth, ahead of the desire to take advantage of government incentives for R&D, to take advantage of infrastructure support, to tap local R&D manpower, or to take advantage of technological capabilities of local organizations (Table 4.8.2). In summary, therefore, local firms' decision to establish R&D in Singapore is also primarily driven by competitive considerations (albeit global ones in contrast to regional ones in the case of foreign firms), and only secondarily by what Singapore has to offer.

The obvious implication from the above observation is that, while Singapore government's efforts to promote R&D in Singapore through incentive schemes and infrastructure support upgrading do contribute importantly to influencing the extent of R&D activities in Singapore, particularly by foreign firms, the firms themselves must see the need for R&D as a strategic response to competition, whether globally or regionally, in the first place. Another obvious implication is that the quality and availability of local R&D manpower resources and technological capabilities of local R&D institutions in Singapore are still relatively weak, given that they have been perceived as less significant factors than government incentives for R&D and general infrastructure support. Rather than being the primary strengths that attract R&D investments in certain other countries or regions, R&D manpower and indigenous R&D institutions appear to be the weak link in Singapore's attempt to make itself a global hub for R&D activities.

Table 4.8.1 Criteria Used for Foreign Companies Establishing R&D Function

Significance of Criteria of Following for Establishing R&D Function in Singapore	% of Response			Total
	Low	Med	High	
To develop/adapt products to local or regional markets	11.5	8.2	80.3	100%
To be close to lead users/customers	13.1	9.8	77.1	100%
To enhance local manufacturing capabilities	24.6	16.4	59.0	100%
To establish a "center of excellence" in the Asia-Pacific region	14.8	27.9	57.3	100%
To take advantage of excellent infrastructure support	17.7	30.6	51.6	100%
To take advantage of government incentives for R&D activities	21.0	32.2	46.8	100%
To tap local R&D manpower resources	17.7	41.9	40.3	100%
To take advantage of technological capabilities of local organizations	29.0	33.9	37.1	100%

Table 4.8.2 Criteria Used for Local Companies Establishing R&D Function

Significance of Criteria of Following for Establishing R&D Function in Singapore	% of Response			Total
	Low	Med	High	
To keep up with technological changes in the market	2.3	9.1	88.6	100%
To develop innovative products for the global market	2.3	13.6	84.1	100%
To develop/adapt products to local or regional markets	16.7	9.5	73.8	100%
To support the internationalization drive of the company	7.3	19.5	73.2	100%
To support own manufacturing/ processing capabilities	20.9	7.0	72.1	100%
To take advantage of government incentives for R&D activities	20.5	15.9	63.6	100%
To take advantage of excellent infrastructure support	25.0	22.7	52.3	100%
To tap local R&D manpower resources	27.9	20.9	51.2	100%
To take advantage of technological capabilities of local organizations	25.6	25.6	48.9	100%
To reduce dependence on foreign technology suppliers	30.2	20.9	48.8	100%
To move away from subcontract manufacturers to innovate own products	32.5	25.6	41.9	100%

4.9 Major Differences Among Foreign Firms from US, Japan and Europe

In the Global Benchmarking Study by the MIT Team, several major differences were noted among the leading high-tech firms from the US, Japan and Europe. In particular, the study highlighted how Japanese firms appear to manage technology differently from American and European firms in terms of how they link technology to overall corporate strategy, the strategic technology roles of their CEOs, and their R&D allocation priorities. It is thus of interest to analyze from our Singapore survey samples of MNCs whether the same differences can be found, as well as whether there are other strategic dimensions where significant differences exist between American, Japanese and European firms. In view of the somewhat smaller sample size of foreign firms in our survey, however, it is more difficult to detect differences in response that are statistically significant. Moreover, as pointed out earlier, the respondents in our survey represent senior managers in overseas regional or national subsidiary operations rather than from the parent headquarters, and hence their views may not completely reflect those of the parent organization. In particular, their views on strategy at the business unit level are in reference to their company operation in

Singapore (or the region, if they are regional headquarters), rather than to their corporations' overseas operations in general, and hence may reflect concerns that are specific to Singapore and the surrounding region, and which are not generalizable to the corporations' strategic concerns world-wide. Finally, although many of the largest MNCs in the world are represented in our Singapore survey, the survey also covers quite a few smaller MNCs that are not in the league of companies in the MIT Global Study.

With the above caveats in mind, we highlight in this section some of the key strategic dimensions in which Japanese firms appear to be significantly different from American and European firms.

4.9.1 The CEOs of American, European and Japanese firms appear to emphasize different strategic roles in relation to technology.

As was found in the Global Benchmarking Study, American CEOs appear to emphasize most on overall R&D budget determination, whereas CEOs of Japanese firms place greater importance on selection and prioritization of technologies, while CEOs of European firms put equal emphasis on directing technology strategy development and R&D budget determination (Table 4.9.1). Overall, of the five key dimensions of involvement in strategic technology management, CEOs of Japanese firms show a greater level of involvement than American firms in four dimensions (except in setting overall R&D budget), with the Europeans somewhere in between.

Table 4.9.1 Strategic Roles of CEO by Location of Headquarters

Involvement of CEO who Directs the Following:	% of Respondents		
	US	Europe	Japan
Technology strategy development	25.0	40.0	31.8
Project selection/prioritization	12.5	20.0	40.9
Establishment of overall R&D budget	45.8	40.0	36.4
Internal technology resource allocation	12.5	13.3	13.6
Selection of outside technology investments	20.8	20.0	40.9

4.9.2 Unlike in the Global Benchmarking Study, there appears to be no significant difference in the perceived level of development and acceptance of technology strategy between American and Japanese firms.

However, European firms do appear to lag behind (Table 4.9.2).

Table 4.9.2 Extent of Development and Acceptance of Corporate Technology Strategy by Location of Headquarters

Extent of Development and Acceptance of Technology Strategy	% of Response		
	US	Europe	Japan
Vague or virtually non-existent	9.1	7.1	0.0
Exists and is communicated to the organization, but not well understood or accepted	9.1	35.7	19.0
Understood by organization but not generally accepted	9.1	0.0	19.0
Communicated to and accepted by the organization as a whole	72.7	57.1	61.9

4.9.3 **Similarly, unlike in the Global Benchmarking Study, our survey sample of American, Japanese and European firms does not exhibit significantly different ways of linking technology to corporate strategy.**

Both the CEOs and the CTOs (or their equivalents) are perceived to play important roles in providing this linkage, whether at the corporate or business unit level, for American, European and Japanese firms alike. In particular, the special significance of CFO in the case of Japanese firms as found in the Global Study by the MIT team is not duplicated in the Singapore study. Also, in linking technology to business unit strategy, Business Unit Managers appear to have distinctly smaller role in general compared to the MIT Global Study, and in Japanese firms in particular (Table 4.9.3).

Table 4.9.3 Critical Positions to Achieving Linkage to Corporate/Business Unit Strategy by Location of Headquarters

Most Critical Roles/Positions	% of Response					
	Corporate Strategy			Business Unit Strategy		
	US	Europe	Japan	US	Europe	Japan
CEO	56.5	42.1	53.8	36.4	30.0	48.1
CTO	21.7	5.3	15.4	4.5	5.0	14.8
R&D VP/Director	13.0	21.1	11.5	27.3	25.0	14.8
COO	8.7	5.3	3.9	9.1	0.0	3.7
Marketing VP/Director	0.0	10.5	11.5	4.5	10.0	14.8
Finance VP/Director	0.0	5.3	0.0	0.0	5.0	0.0
Business Unit Managers	0.0	10.5	3.9	18.2	25.0	3.7

4.9.4 **Both European and Japanese firms have a higher proportion of CTOs (or their equivalent) represented in the board of directors than American firms.**

This finding is consistent with the findings from the Global Benchmarking Study. The Japanese and European response may have been biased downward in the Singapore survey, as many Japanese and European firms do not have formal CTO positions. Although the survey questionnaire asks the respondents for CTO or their equivalents, some Japanese and European firms may not have included their CTO equivalent in responding to the above question.

Table 4.9.4 CTOs on the Board of Directors by Location of Headquarters

CTO or Equivalent Sitting on Board of Directors	% of Response
US	35.0
Europe	61.5
Japan	50.0

4.9.5 **Compared to their American and European counterparts, Japanese companies that operate in Singapore appear to approach internal technology development differently.**

Japanese firms rely relatively more than American and European firms on corporate R&D to obtain technology than R&D within divisions or business units (Table 4.9.5a), and derive more of their corporate R&D funding from business unit support (Table 4.9.5b). Moreover, their R&D functions tend to be accorded higher status in the corporate organization, as reflected in their higher likelihood of getting the R&D budget they requested (Table 4.9.5c), and in having more say in determining the type of customer inputs that they need (Table 4.9.5d). In terms of R&D budget allocation, more of the R&D resources in Japanese firms are allocated to product/process support (Table 4.9.5e). Finally, Japanese firms exhibit an overall tendency towards centralization of both research and development activities, while European firms are decentralizing both, with American firms decentralizing development but centralizing research (Table 4.9.5f).

Table 4.9.5a Internal Mechanisms to Obtain Technology by Location of Headquarters

Internal mechanisms to obtain technology (High extent)	% of Response					
	Research Work			Development Work		
	US	Europe	Japan	US	Europe	Japan
Central corporate research	73.9	69.3	72.7	39.1	42.9	57.1
Internal R&D within divisions	52.2	71.4	42.8	91.3	80.0	81.8

Table 4.9.5b Funding of Corporate-Level R&D Function by Location of Headquarters

Amount the Following Options Contribute to Corporate-Level R&D Function	% of Respondents Citing Most Important Option		
	US	Europe	Japan
Corporate	55.0	50.0	35.3
Business units as fixed %	45.0	33.3	33.3
Business units on direct project by project basis	15.0	37.5	43.8
Outside of the company	0.0	0.0	0.0

Table 4.9.5c Extent of R&D Support by Location of Headquarters

Extent of Support R&D Gets	% of Respondents Citing High Support		
	US	Europe	Japan
R&D typically gets amount of money it requests for its budget	29.2	33.4	54.6
Top management's attitude toward R&D is highly supportive	83.3	66.7	68.2

Table 4.9.5d Obtaining External Customer Input in Research/Development by Location of Headquarters

How External Customer Input is Obtained	% of Response					
	Research			Development		
	US	Europe	Japan	US	Europe	Japan
R&D determines what customer inputs it needs, and obtains them	25.0	40.0	47.6	12.5	26.7	25.0
R&D identifies what customer inputs it requires, but another organizational entity obtains them	29.2	26.7	19.0	12.5	20.0	15.0
Other organizational entities have the responsibility to determine customer inputs, they obtain them and do an adequate job of transferring the information to R&D	45.8	13.3	19.0	66.7	33.3	35.0
Other organizational entities have the responsibility to determine customer inputs, but do an inadequate job in obtaining and transferring the information	0.0	20.0	14.3	8.3	20.0	25.0
Total	100%	100%	100%	100%	100%	100%

Table 4.9.5e Mean % of Funds Allocated for Corporate vs. Business Unit RD&E Budget by Location of Headquarters

R&D Activity	Corporate RD&E			Business Unit RD&E		
	US	Europe	Japan	US	Europe	Japan
Research	26.1	23.8	16.0	10.2	8.7	12.6
Development	35.0	38.5	35.2	36.4	44.2	35.5
Product technical support	23.1	19.6	25.0	36.3	31.6	31.7
Process technical support	15.8	10.4	21.2	17.4	15.6	20.8

Table 4.9.5f Changes in Control of Technology Resources by Location of Headquarters

Changes in Control of Technology Resources	% of Response					
	Research			Development		
	US	Europe	Japan	US	Europe	Japan
Less corporate-level control today	29.2	13.3	27.3	50.0	26.7	36.4
About the same corporate-level control today as 3 years ago	33.3	40.0	59.1	16.7	33.3	40.9
More corporate-level control today	37.5	46.7	13.6	33.3	40.0	22.7
Overall	100%	100%	100%	100%	100%	100%

4.9.6 **Japanese companies also differ from American and European firms in their approaches to external technology acquisition in support of their internal R&D activities.**

While both American and European firms give greater emphasis to outright acquisition and joint venture/alliance, Japanese firms give greater emphasis to incorporating innovative technologies from their suppliers and from licensing (Table 4.9.6).

Table 4.9.6 Top 4 Mechanisms to Acquire Technology for Research and Development Work by Location of Headquarters

US		
Top 4 mechanisms for research work		Top 4 mechanisms for development work
#1)	Joint venture/alliance	Technology acquisition
#2)	Technology acquisition	Product acquisition
#3)	Incorporation of supplier's technology	Incorporation of supplier's technology
#4)	Incorporation of customer's technology	Incorporation of customer's technology
Europe		
Top 4 mechanisms for research work		Top 4 mechanisms for development work
#1)	Technology acquisition	Incorporation of supplier's technology
#2)	Product acquisition	Technology acquisition
#3)	Companies acquisition	Incorporation of customer's technology
#4)	Consultants/Contract R&D	Product acquisition
Japan		
Top 4 mechanisms for research work		Top 4 mechanisms for development work
#1)	Incorporation of supplier's technology	Licensing
#2)	Technology acquisition	Incorporation of supplier's technology
#3)	Licensing	Incorporation of customer's technology
#4)	University liaison/affiliate programs	Technology acquisition

4.9.7 **Japanese firms on the whole make greater use of university programs for technology monitoring/acquisition than American firms, with European firms the least.**

Moreover, while American firms emphasize the most using their contact with universities to determine technology needs foremost, Japanese firms emphasize most on collaborative research efforts (Table 4.9.7).

Table 4.9.7 Usage of University Programs for Technology Monitoring/Acquisition by Location of Headquarters

Usage of University Programs for Technology Monitoring/Acquisition (High Usage)	% of Response		
	US	Europe	Japan
Collaborative research efforts	17.3	14.2	31.8
Obtaining innovative ideas	17.4	14.2	27.3
Determining technology trends	26.1	7.1	22.7
Training company personnel	21.7	14.2	27.2
Modifying technology management practices	17.4	7.1	9.1
Licensing product innovations	0.0	7.1	13.6
Licensing process innovations	0.0	7.1	4.5

4.9.8 **Overall, compared to US and European firms, Japanese firms accord more importance to training of existing people and continuous education as a means to develop and/or acquire new technology.**

In particular, while both American and European firms resort quite a bit to hiring experienced people from competitors, Japanese firms tend not to adopt such a practice (Table 4.9.8). Continuous education also figures more prominently among Japanese firms as a mechanism for obtaining external technology (Table 4.9.6). Finally, Japanese firms have the highest usage of university programs to train company personnel (Table 4.9.7).

Table 4.9.8 Acquisition of New Technological Skills by Location of Headquarters

Importance of Following for Acquisition of New Technological Skills (Most Important)	% of Response		
	US	Europe	Japan
Hire new people directly from universities	20.8	20.0	13.6
Hire experienced people from competitors	33.3	40.0	9.1
Train/retrain existing people	58.3	40.0	77.3

4.9.9 **As was true in the Global Benchmarking Study, American firms generally rate themselves as being more extensively involved in incorporating the "voice of the customer" into their R&D process than Japanese and European firms.**

However, unlike in the Global Benchmarking Study, European firms appear to be almost as extensively involved as the American firms, with Japanese being the laggards (Table 4.9.9).

Table 4.9.9 Use of Direct Customer Input by Location of Headquarters

Use of Direct Customer Input for Following Technology Activities (High Usage)	% of Response		
	US	Europe	Japan
Product improvement	91.6	86.7	77.1
Product refinement/ commercialization	79.2	80.0	63.7
Setting program objectives	70.8	60.0	59.1
Technology strategy development	70.8	53.3	63.6
Testing	58.3	60.0	40.9
Concept development	58.3	53.4	50.0
Prototype development	50.0	60.0	36.4
Obtaining innovative ideas	37.5	40.0	31.8

4.9.10 **Japanese firms appear to establish their non-domestic R&D activities more to focus on particular phase of their overall R&D process, rather than to establish world-wide centers of excellence for a particular technology which is more prevalent among European and American firms.**

Moreover, Japanese firms seldom perform the same R&D activities overseas as in their domestic facilities (Table 4.9.10). This suggests that Japanese firms' overseas R&D may be much more vertically integrated with domestic R&D than in the case of American or European firms. It could also mean that Japanese firms' R&D overseas is more geared to product adaptation/technical support.

Table 4.9.10 Function of Company's Non-Domestic R&D Facilities by Location of Headquarters

Function of Non-Domestic R&D Facilities	% of Response		
	US	Europe	Japan
Perform the same activities as domestic R&D facilities	33.3	30.0	7.7
Represent worldwide "centers of excellence" for a particular technology, discipline	38.1	50.0	23.1
Focus on a particular phase of the R&D process	28.6	20.0	69.2
Overall	100%	100%	100%

4.9.11 **Lastly, American firms appear to differ somewhat from Japanese and European firms in terms of their key motivation to establish R&D in Singapore.**

The 3 most important reasons for American firms are to be close to the lead users/customers, to take advantage of government incentives, and to establish a "center of excellence" in the Asia Pacific region. In contrast, both Japanese and European firms stressed development/adaptation of products to local/regional market as most important, while enhancing local manufacturing and being close to lead users/customers are among the top 3 reasons (Table 4.9.11).

Table 4.9.11 Criteria Used to Establish R&D Function by Location of Headquarters

Significance of Criteria of Following for Establishing R&D Function in Singapore	% of Response		
	US	Europe	Japan
To develop/adapt products to local or regional markets	63.7	100	81.7
To be close to lead users/customers	82.6	84.6	66.6
To enhance local manufacturing capabilities	50.0	92.9	57.1
To establish a "center of excellence" in the Asia-Pacific region	65.2	57.2	50.0
To take advantage of excellence infrastructure support	60.9	42.8	42.9
To take advantage of government incentives for R&D activities	69.5	35.7	28.6
To tap local R&D manpower resources	47.8	21.4	47.6
To take advantage of technological capabilities of local organizations	47.8	7.1	42.9

5. CONCLUSION

This study represents a first attempt at benchmarking the current strategic concerns and practices related to the management of technology among leading high-tech firms in a newly industrialised economy (NIE) - Singapore. The study yields interesting insights not only on the overall status of technology management strategies among these firms, but also highlights salient differences between local and foreign firms, as well as among foreign firms from the US, Japan and Europe.

It is hoped that high-tech companies operating in Singapore would find the study findings useful in providing a reference benchmark to compare and contrast their own technology management practices and concerns. We also hope that the insights on the strategic concerns and behavior among high-tech firms in Singapore as derived from the study would be useful to various government agencies involved in the promotion of technological innovation and high-tech industry development in Singapore.

Moving forward, the study team will be conducting a systematic comparative analysis of our findings for Singapore-based firms with those of the MIT Global Benchmarking Study covering the largest, most technologically intensive firms in the world. Our preliminary comparative analysis of the Singapore study with the MIT Global Study confirms that Singapore-based firms are generally behind the largest, most technologically intensive firms in the world in terms of obvious benchmarks such as research intensity, degree of internationalization of R&D activities and technology acquisition mechanisms, but a more in-depth comparative analysis will be necessary to obtain additional insights, which we plan to report in a future publication.

The study team also plans to refine its analysis of the Singapore benchmark data by focusing in greater depth on the strategic issues in specific industrial sectors that are important in Singapore (e.g. electronics, information technology, materials/chemicals), through increasing the number of company responses in these selected sectors and exploring in greater detail the issues specific to the industries concerned. In-depth case studies of specific companies are also planned to complement our overall benchmarks with documentation of individual company practices. Together with the MIT Global Study team, we also plan to broaden the geographical coverage of our Singapore benchmarking database with the addition of other Asian NIEs. Finally, to keep up with the rapid changes expected over the next few years, the study team hopes to repeat the Singapore benchmarking study in future years in tandem with the MIT Global Survey to monitor how Singapore firms fare relative to the global leaders as well as to capture the latest issues and innovation practices related to the strategic management of technology.

APPENDIX: SURVEY METHODOLOGY

Questionnaire Design

The questionnaire design adopted in the Singapore survey followed closely the original questionnaire design developed by the MIT team for the global survey of leading American, Japanese and European high-tech firms. However, some questions are modified to suit the local context.

Survey Frame

The survey coverage includes all 331 firms that indicated some formally organized R&D activities as reported in the National R&D Census conducted by NSTB in 1993. In addition, a number of companies which are known to the research team as having initiated R&D activities, but which were not included in the list supplied by NSTB, were compiled and added to the survey frame. Some additional companies which have been in contact with the Industry and Technology Relations Office (INTRO) at the National University of Singapore, and which are known to have in-house R&D activities, were also added to the survey frame. After subsequent checking and elimination of companies that have ceased R&D activities or company operations altogether, a total valid universe of 385 companies was obtained.

The questionnaire was mailed out in 3 batches from January to February of 1994, with two reminder letters sent to those that did not respond in March and April. Follow-up telephone calls were also made to remind companies that did not respond as well as to seek clarifications on certain items of their returned questionnaire. The survey was closed at the end of May.

Where the companies came from the NSTB R&D Census list, the respondent names for the Census were used. These include mainly top management (CEOs, General Managers, Managing Directors, Corporate Planning) or senior technology managers (R&D directors, VP for Technology/Engineering, etc.), although some were addressed to other senior managers (Administrative/Personnel Directors, Finance/Accounting, etc.). The questionnaires for the other companies were addressed to the contact persons known to the researchers or to INTRO, who invariably are senior technology managers of the respective companies. The covering letter to the questionnaire did request for the questionnaire to be filled by the corporate chief technology officer, his/her equivalent or designate, and although there is no way to verify whether this is indeed done in every case, the experience of the researchers in follow-up telephone calls with selected companies do suggest that the respondents have been appropriately chosen.

Survey Responses

The initial questionnaires were edited and checked for any shortcomings, for example in missing or uncompleted responses. They were fed back to and verified by the respective companies' respondents. A total of 103 valid and usable responses, or 27% of the valid universe, were achieved at the close of the fieldwork at the end of May.